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**CHEMISTRY**  
**EXPERIMENTS AT HOME**  
**FOR BOYS AND GIRLS**

"Why," said the Dodo, "the best way to explain it is to do it."

*Alice's Adventures in Wonderland*

542

# CHEMISTRY EXPERIMENTS AT HOME FOR BOYS AND GIRLS

*Containing instructions for boys and girls of eleven to eighteen on how to set up a Chemistry laboratory at home, and how to carry out over three hundred safe, easy, and interesting experiments, including the preparation of invisible inks, glass, soap, plastics, and artificial silk, the growing of crystals, the performing of chemical magic, the collecting of gases, etc., etc.*

BY

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"PHYSICAL CHEMISTRY FOR SCHOOLS AND COLLEGES"

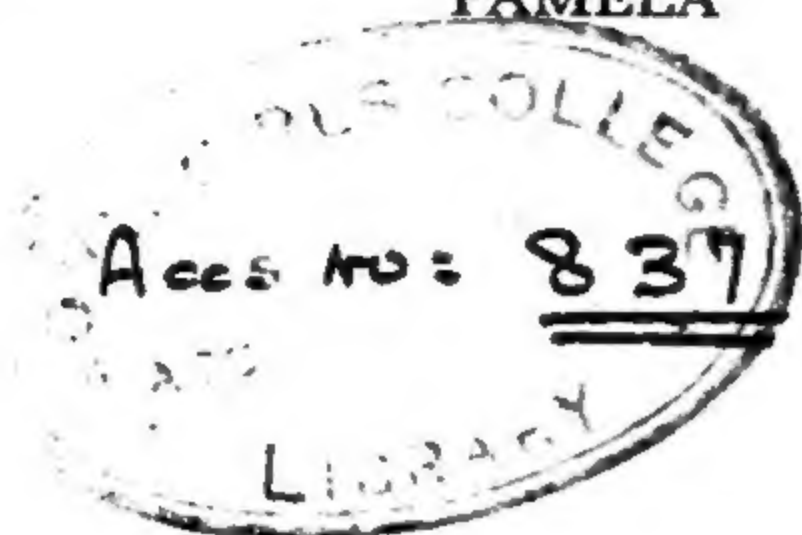
WITH ILLUSTRATIONS AND DIAGRAMS



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TO  
MY DAUGHTER  
PAMELA



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## *Preface*

THIS is a Chemistry book which is different; for while it is not a text-book, it is something more than a play-book. It is intended for boys and girls of eleven to eighteen who wish to pursue Chemistry at home as a hobby. A large proportion of those who study Chemistry at school nowadays become sufficiently interested to want to do experiments for themselves. The author recently held an inquiry among boys of the twelve to thirteen age-group in his own school and found that over half of them carried out experiments with their own chemicals at home. This enthusiasm is excellent from the educational point of view. Admittedly a considerable number never pass beyond the stage of a temporary and superficial interest in fireworks and stink-bombs, but in many cases, given suitable guidance, natural curiosity can be deepened into a lasting affection for Science.

Chemistry as a hobby provides a first-rate training in scientific method which is complementary to the more formal instruction in the school laboratory. The improvising of apparatus and the solving of practical problems for oneself are invaluable in developing personal initiative and reasoning power. It should not be forgotten that many of the founders of modern Chemistry—such as Joseph Priestley and John Dalton—were themselves amateur scientists, who did their experiments at home with limited materials.

Unfortunately, at the present time Chemistry as a hobby for boys and girls is acquiring rather a sinister reputation. Accidents occur through experimenting with dangerous chemicals and are duly reported in the Press. The real cause of the trouble is that youngsters have little to guide them in the way of safe but interesting experiments which they can do. It is hoped that this book will fill the gap and enable budding chemists to satisfy their urge to experiment without undue risk to themselves. To discourage a hobby which is both harmless and educational is unwise at any time. It is particularly regrettable to-day, when the attractions of the cinema, wireless, and more doubtful forms of entertainment are weakening the hold of the traditional hobbies on young people.

The author has had over twenty years' experience of teaching Chemistry to boys of all ages, but for the purposes of this book he has forgotten that he is a Chemistry master. He used the materials described, and performed the experiments given, under the conditions which usually exist for boys and girls at home. Some of the experiments are adaptations of old and well-known experiments, but



many—for example, the method of growing crystals—are, as far as the author is aware, entirely new. The only advantage which the author has enjoyed has been his greater experience, and this he places at the disposal of the reader in the following pages.

The author wishes to thank all who have helped in the production of this book. Mr W. E. Jones, of the Liverpool Collegiate School, has given valuable assistance with the diagrams and made many useful suggestions, particularly on glass-working. Mr R. H. Gardener, General Manager of Plastics (Manchester), Ltd, has contributed much information on the working of sheet plastic. The author is also indebted to Mr L. A. Naylor, M.A., of the Liverpool Institute for Boys, for reading the manuscript of the book in proof, correcting errors, and suggesting improvements. Finally, the author's thanks are due to E. Johnston, a pupil of the Liverpool Collegiate School, who posed for photographs shown in Plates 3 and 6.

H. L. H.



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## *The Sale of Chemicals to Juniors*

A RECENT Annual Report of His Majesty's Inspectors of Explosives announces a large increase in the number of accidents caused by the illegal manufacture of fireworks. At the request of the Home Office the Pharmaceutical Society of Great Britain has circularized all pharmacists in the country asking that certain substances should not be sold to children under sixteen years of age. Pharmacists are further requested to ensure that when any demand for these substances is made by persons of sixteen to eighteen reasonable steps will be taken to ascertain that they are required for a proper purpose and will not be used by the purchaser for making explosives or fireworks, nor handed to younger children for that purpose.

None of the substances specified by the Pharmaceutical Society is included for experimental purposes in this book, nor are instructions given for the making of any fireworks or explosives. The author's purpose is to show boys and girls who are interested in Chemistry what experiments can be safely carried out at home.

## *A Few Words to the Young Chemist*

CHEMISTRY experiments at home! Like most boys and girls, you probably feel a thrill at the thought of performing experiments for yourself. Perhaps you have watched a master or mistress at school producing beautiful colours, horrible smells, or startling explosions, and now you think you can do something for yourself on these lines. You may be the proud owner of a brand-new Chemistry set or you may only have gathered together a few chemicals and test-tubes with your precious pocket-money. It makes no difference. Carrying out experiments for oneself is a thousand times more exciting than watching other people do them.

Now, there is much more in Chemistry than just making colours, 'stinks,' and bangs. If you carry out the experiments described in the following pages you will learn a lot of useful knowledge about chemicals and acquire skill in handling apparatus. Instead of just playing at Chemistry, you will become a real chemist. Again, if you are really interested in Chemistry you will want to know why things happen as they do. The author has therefore included a certain amount of explanation to help you to understand the results of your experiments.

It is not necessary to have a lot of expensive chemicals and apparatus to do experiments at home. Indeed, many of the most interesting experiments can be performed with substances found in almost every household, and a great deal of apparatus can be made from simple materials at home. The construction of home-made apparatus is itself part of the fun. This book is written to help you. It tells you how to build up a good chemical outfit cheaply, how to look after it, and how to do a large number of interesting experiments. In particular it shows you how to make the fullest use of the materials which you can find at home, so that your pocket-money need be spent only on those things which are absolutely necessary.

A famous chemist, William Perkin, was only eighteen when he discovered a wonderful new dye while experimenting at home with his own chemicals. This discovery was the beginning of the great modern dyestuffs industry. Who knows but that *you* may surprise the world some day by a similar marvellous discovery?

## *General Hints and Precautions*

To obtain the greatest enjoyment and benefit from Chemistry as a hobby you must learn to do your experiments in the proper way. We should have a poor opinion of a plumber who spilled his solder all over the floor, burned the kitchen-table, and finally blew up the gas-boiler. Similarly, unless you go about things in the correct manner your experiments will fail, your apparatus will break, your chemicals become messy, and after a few tries you will probably give up in disgust. For this reason we start by giving the young chemist a few hints on the performing of experiments at home.

(1) Begin by doing very simple experiments. You will then get accustomed to handling the chemicals and apparatus.

(2) Read the instructions carefully, and follow them as closely as possible. This will avoid wasting your materials.

(3) Protect the surface of the table, bench, or wherever you are working by means of a sheet of asbestos, an old drawing-board, or something similar. If nothing else is available use two or three sheets of cardboard. When chemicals are spilled on a table they often leave ugly stains.

(4) Wear old clothes—or at least an old coat—and wipe your hands on an old duster, not on your clothes.

(5) If you spill chemicals wipe them up at once.

*Prompt treatment will prevent damage.* Liquids should be mopped up with a damp cloth, which should then be rinsed out and used again. If the liquid has got on to your clothes, test the affected part with a piece of blue litmus paper. If the chemical is acid (blue litmus turns red), dab weak ammonia on the place to neutralize the acid—otherwise the acid may 'burn' a hole in the cloth. Acid on the skin can be rendered harmless by prompt washing with water. No experiments with dangerous strong acids are given in this book.

(6) Never perform experiments which you know to be risky. The author has not included such experiments. The excitement of playing with dangerous chemicals is not worth the risk of losing an eye or getting badly burned.

(7) Never taste chemicals. Some would make you sick, but a few are poisonous. Keep all vessels used for chemicals quite separate from vessels used in the household.

(8) Do not throw chemicals on the fire. After use, liquids and powders should be washed straight down the sink with plenty of water. Bigger pieces of waste-matter should not be put into the sink, but should be thrown away outside.



(9) Do not work with broken test-tubes, beakers, etc. Jagged edges on glass are very dangerous.

(10) Never play practical jokes on other people with your chemicals. You may injure somebody severely.

(11) When you have finished your experiments, clean your apparatus before putting it away in a safe place. Apparatus left dirty is twice as difficult to clean later on and is a sign of bad workmanship.

(12) Do not annoy your mother by spilling chemicals, leaving apparatus lying about, or wanting to work in the kitchen when she is making dinner. It is important to have your mother on your side, because she can let you have lots of things which are useful for doing experiments.

## CHAPTER I

### *How to fit up a Home Laboratory: Chemicals and Apparatus*

If you are starting off with one of the several makes of Chemistry set which are sold your stock of materials will depend a good deal on how much the set has cost. The cheaper sets seldom contain sufficient chemicals and apparatus to do many experiments. The best and cheapest way of doing Chemistry at home is to build up your stock for yourself. There are two ways of doing this,

- (i) by using the materials to be found at home, and
- (ii) by buying from a reliable dealer or from a chemist's shop.

An address from which chemicals and apparatus can be bought by post is given at the end of the book (p. 231).

### CHEMICALS

Your chemicals should be kept, not in paper packets, but in small bottles or jars fitted with corks or stoppers. Many chemicals on exposure to air become wet and messy or spoil in other ways. You should, therefore, collect as many small bottles or jars as you can. They should preferably be made of plain, not coloured, glass so that you can see the substances inside. Empty ink bottles, medicine bottles, vaseline jars, etc., are suitable.

Swill the bottles or jars out with warm water. If they are greasy, get rid of as much grease as possible with a rag and leave them to soak for a time in warm soapy water. Remove the old labels, allow the bottles to drain after washing, and then leave them to dry in a warm oven or in the bottom of the airing-cupboard.

When the bottles are dry, use those with wide necks for solid chemicals and those with narrow necks for liquid chemicals (Fig. 1). Attach to each bottle or jar a gummed label on which you

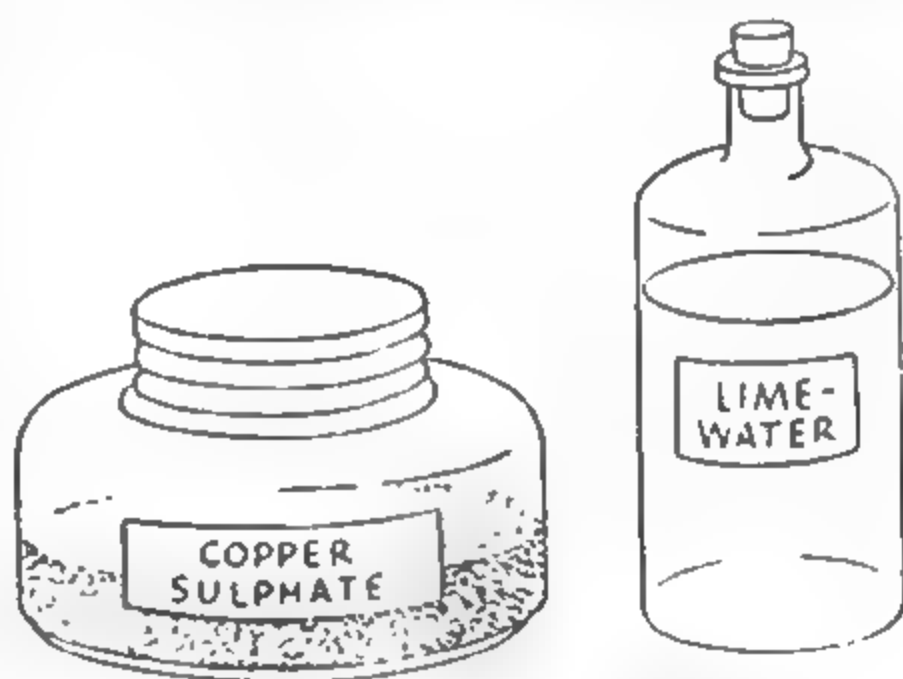


FIG. 1. BOTTLES USED FOR SOLID AND LIQUID CHEMICALS

have printed the name of the chemical. Common substances often have two names, an everyday name and a chemical name. Thus blue vitriol is the everyday name for some well-known blue crystals, while the chemical name for the same crystals is copper sulphate. It is a good idea to write both names on your labels if you are not sure of them.

It will probably be some time before you can build up a complete set of the chemicals mentioned in this book. In the meantime the list given below is a suitable selection of solid and liquid substances which will enable you to make a start. With these you will be able to carry out the simple experiments described in Chapter III and also many of the experiments described in the later chapters.

Very likely you will find several of the substances mentioned—for example, baking-soda—in the kitchen-cupboard or first-aid cabinet, but you should be able to buy at little cost those which you cannot obtain in this way. The approximate prices of the chemicals used in this book are given at p. 231. Suitable amounts to buy at first are shown in brackets in the following list.

### *Solids*

Baking-soda (1 oz.)	Boracic acid (1 oz.)
Washing-soda (8 oz.)	'Hypo.' (1 oz.)
Starch (1 oz.)	Cobalt chloride ( $\frac{1}{2}$ oz.)
Alum (1 oz.)	Citric acid (1 oz.)
Ferrous sulphate (1 oz.)	Iron filings (2 oz.)
Copper sulphate (1 oz.)	Sodium bisulphate (2 oz.) <sup>1</sup>

### *Liquids*

Lime-water	Hydrogen peroxide
Ammonia (dilute)	Phenolphthalein
Iodine solution	Sulphuric acid <sup>1</sup>

Ammonia solution of the right strength is made by adding five parts of water to one part of clear household ammonia. When you buy liquids from a chemist's shop it is best to take your own bottle. Lime-water is cheap; you can obtain a large bottleful for twopence or threepence. Ordinary tincture of iodine used for putting on cuts is quite satisfactory. This and phenolphthalein (pronounced 'feenolf-thaleen') are expensive, partly because they are sold dissolved in alcohol. Phenolphthalein, however, is an interesting chemical, and, as only one or two drops are used each time, it is worth buying, say, sixpennyworth of the solution in a small bottle.

Dilute sulphuric acid can be bought at a chemist's. An alternative source is a wireless shop which handles accumulators, but this accumulator acid is fairly strong and must be handled carefully.

<sup>1</sup> Sodium bisulphate is given because it can be used in solution instead of sulphuric acid in most experiments and is often obtained more easily (see p. 88).

It should be diluted by adding one part of acid to three parts of water.

Some solid chemicals are used frequently in solution. It saves a good deal of time and trouble if you make up a fairly large amount of the solution to begin with, so that you can use small amounts of solution from your 'stock' as required. A solution of suitable strength can be made by stirring one teaspoonful of the solid chemical in half a tumblerful of water. Remember to wash out the tumbler between each dissolving.

#### *Stock solutions of solids*

Copper sulphate  
Alum  
Citric acid

Washing-soda  
Sodium bisulphate

### APPARATUS

A Chemistry set usually contains a certain amount of apparatus. The most satisfactory method of acquiring apparatus, however, is probably to buy it for yourself a little at a time. While you are doing this you can in many cases use substitutes which you can find at home or make in the manner described. The following can be considered as the minimum apparatus needed to start your home laboratory: (i) a few test-tubes, (ii) a funnel, (iii) a beaker, (iv) filter-papers, (v) some method of heating. Other items of apparatus mentioned in the following pages can be added gradually as circumstances allow.

*Test-tubes.* At least half a dozen of these should be bought. The best size for ordinary work is  $5'' \times \frac{5}{8}''$ —that is, 5 inches long and  $\frac{5}{8}$ -inch across the top. The cost for this size is about 10d. a dozen. It is an advantage to have also a 'hard-glass' tube in which chemicals can be heated strongly without melting the glass. A tube of this kind costs about 5d.

Small ignition-tubes (p. 34) can often be used for heating a substance strongly. A larger tube, measuring 6 in.  $\times$  1 in. and called a boiling-tube, is often more convenient to use than an ordinary test-tube when you want to boil a liquid. It costs 2d.

*Funnel.* For filtering liquids a glass funnel is usually employed. The most suitable size has a diameter of 3 inches across the top, and costs about 9d. A Bakelite funnel can be bought for 5d. at Woolworth's, and is quite serviceable.

*Beaker.* One holding 250 c.c. of liquid is a handy size, and costs about a shilling. A jam-jar (one-pound size) can often be used as a substitute for a beaker.

*Filter-papers.* For ordinary work these should have a diameter of

11 cm. The cheapest way of buying filter-papers is to invest in a packet of a hundred, at a cost of about 9d. At a pinch a round piece of newspaper can be used as a filter-paper.

*Method of Heating.* Some experiments can be carried out in the cold, but for many some form of heating is required. Without doubt the best method of heating is by means of a Bunsen burner (this costs about 2s. 6d.). The Bunsen burner is connected to a gas supply by a length of rubber tubing. If you have a gas-cooker in the kitchen the rubber tubing can be connected (after removing one of the top grids

and the burner tube below the grid) to the short projecting tube at the side of the cooker.

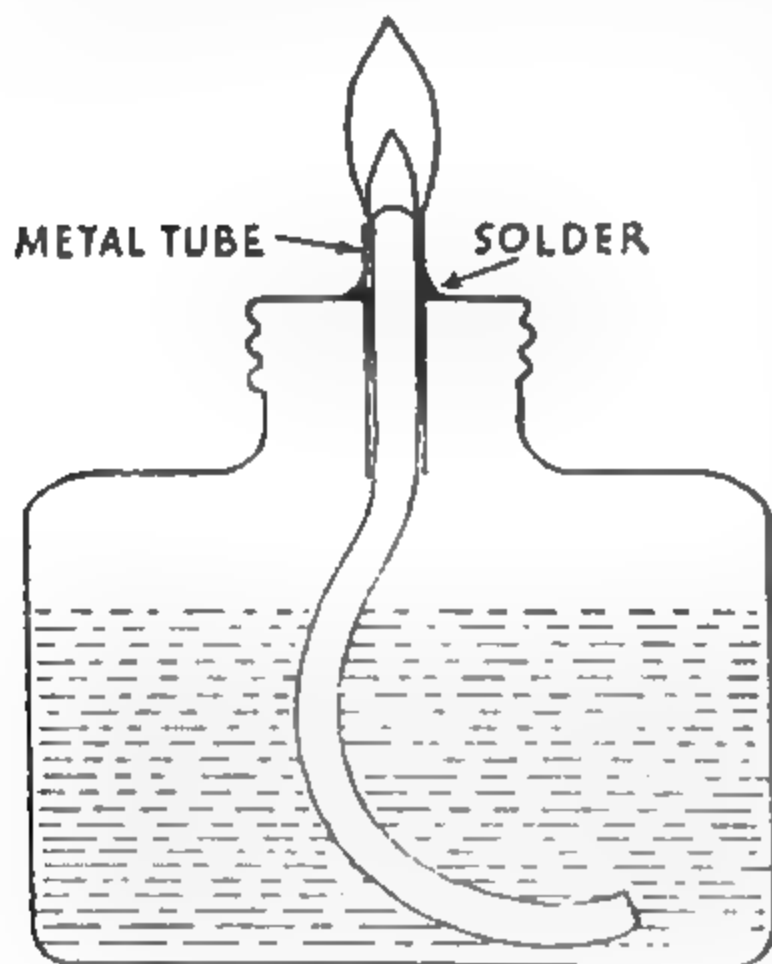


FIG. 2  
A HOME-MADE BURNER

Burners which use paraffin are not recommended, because they give a very smoky flame. The methylated spirit burner provides quite a good method of heating. The flame is not smoky, and, although it cannot be regulated like that of the Bunsen burner and is not very hot, it enables you to do experiments away from a gas supply. This type of burner can be bought for about 2s., and half a pint of methylated spirit costs only a few coppers if you take your own bottle to the chandler's shop or the chemist's.

Fig. 2 (see also Plate 1) shows a methylated spirit burner which can be made at home from a clean ink bottle with a metal screw-cap. You must first obtain a narrow metal tube about one inch long (the metal tube from a small paint-brush is suitable). Clean this thoroughly with sandpaper, and similarly clean the top of the cap. Make a hole in the cap by means of a round nail and hammer so that the metal tube will just pass through the hole. The tube can be fastened in position by applying a little heatless solder round the tube as shown. After applying the solder leave it undisturbed for two or three hours so that it gets a chance to set thoroughly. A wick can be made by plaiting together half a dozen strands of wool. The wick is drawn through the tube by attaching some cotton to the top of the wick and drawing the cotton through first. When using this burner make sure that the cap is screwed down tightly.

**Additional Apparatus.** The above paragraphs deal with what might be called 'necessary' apparatus. Below we give some of the

items which it is desirable for you to have to extend the range of your experiments. In many cases possible substitutes are indicated.

*Evaporating-dish.* A suitable size has a diameter of three inches. Evaporating-dishes are made of porcelain, and are expensive (cost about 1s. 8d.). As a substitute the top of a flat aluminium tooth-paste tin can often be used, but if it is to be heated any paint should first be scraped off with an old knife. The substitute should not be used to evaporate acid or alkaline liquids, as these are likely to attack the aluminium and thus introduce impurities.

*Gauze and Tripod.* Beakers and evaporating-dishes are usually heated by placing them on an iron gauze, which in turn is placed on a tripod. The gauze should preferably have an asbestos centre, which distributes the heat and prevents the beaker or dish from cracking due to too sudden heating. A gauze of this type costs about 6d. and a tripod 2s. 6d.

You can manage without a tripod if you obtain two wooden blocks or square tins of suitable size. The gauze is rested on the tops of the blocks or tins as shown in Fig. 3 (b).

A tripod can be made at home by the method described at p. 118, or it is possible to use as a substitute the wire frame of an old lampshade.

A large tin lid containing sand (or salt) can be used instead of a gauze. When a beaker is being heated on the lid there should be a layer of sand about a quarter of an inch thick below the beaker.

*Test-tube Rack.* There is no necessity to buy a rack to hold your test-tubes. They can be stood in an empty jam-jar, or, better still, a rack can be constructed very easily from a wooden board, a few 3-inch nails, and a length of string.

The board should be about 8 in. long, 4 in. wide, and  $\frac{1}{2}$  in. thick. Plywood is best, but is not essential. First mark out the board by pencil and ruler into inch squares as shown in Fig. 4 (a). At the corner of each square hammer in lightly a 3-in. nail until it just holds (the board will probably split if you drive in the nails too far). Fasten one end of the string round the top of one of the corner nails and wind the string round each nail in turn until every square is enclosed. It will be necessary to run the string twice along some of the sides. Fasten the end of the string to the top of the last nail. You will now have a rack which will hold twelve test-tubes (Fig. 4 (b)).

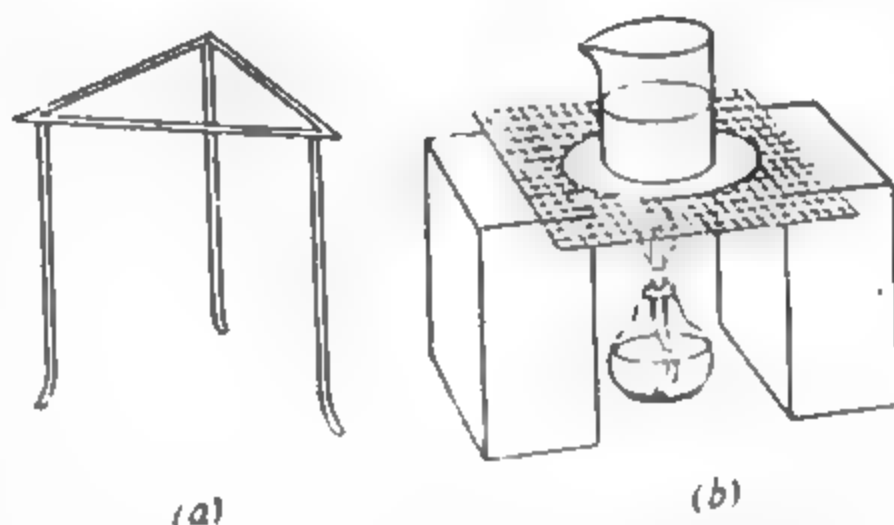


FIG. 3. (a) A TRIPOD, (b) METHOD OF HEATING A BEAKER ON A GAUZE WITHOUT A TRIPOD



and Plate 1). When they are not being used the clean test-tubes should be left upside down in the rack to drain.

*Stand, Boss, and Clamp.* These are sometimes required for holding tubes and flasks which are going to be heated. A small iron stand with the accompanying boss and clamp costs about 8s. 6d., although a cheaper grade made from pressed steel can sometimes be bought. The 'boss' is the small attachment which is screwed on to the upright of the stand. It holds the clamp which in turn supports the apparatus.

A substitute for a stand, boss, and clamp can be made at home at practically no expense as described at p. 115.

*Flask.* Flasks are of two types: (a) round-bottomed and (b) flat-bottomed. The first kind is used when the flask is to be heated, the

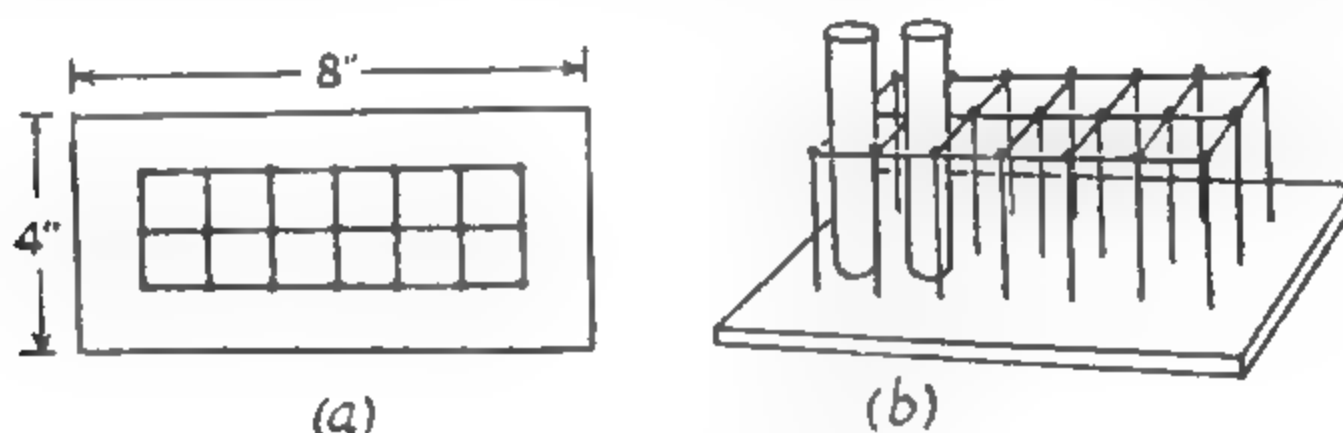


FIG. 4. A SIMPLE TEST-TUBE RACK

second kind for experiments which do not require heat. If you have a stand and clamp to hold it, a round-bottomed flask is probably the more useful. It can be heated directly without using a tripod and gauze. A suitable size, holding 250 c.c., costs about 1s. 6d. A large medicine bottle will often prove a good substitute for a flat-bottomed flask.

When you are putting a flask into a clamp wrap a small roll of paper round the neck of the flask and screw the clamp up only sufficiently to hold the flask. If you are going to heat the flask you must leave room for the neck to expand or it will crack.

*Porcelain Crucible.* This is used for heating a substance strongly. A porcelain crucible is dear, a small size costing about 10d., and is not really necessary. In most experiments where a substance has to be heated strongly a tin-lid or small metal screw-cap from a bottle can be used instead. Metal screw-caps are particularly useful, so keep an eye on all empty bottles which are being thrown away.

*Pipe-clay Triangle.* A crucible which is to be heated strongly is placed, not on a gauze, but on a pipe-clay triangle resting on a tripod. A pipe-clay triangle can be bought for 3d., but it is a simple matter to make a substitute from some stout wire with the help of a pair of pliers. Iron wire which is used for tying up firewood is a suitable



kind of wire to use. If you employ metal screw-caps for strongly heating substances you can hold the screw-caps in a pair of pliers or pincers and a pipe-clay triangle will not be needed.

*Tongs.* Hot objects are usually handled with a pair of tongs, but a pair of pincers or pliers serves the same purpose and saves 10d.

*Mortar and Pestle.* When it is desired to grind a lumpy substance to a powder the lumps are crushed in a mortar with the help of a pestle. A small mortar and pestle made of glass costs about 3s. 6d. You can make a mortar and pestle at home for next to nothing as described at p. 116.

*Test-tube Brush.* The small brushes sold by ironmongers for cleaning bottles can also be used for cleaning test-tubes. A wad of cotton-wool twisted round the end of a stick or knitting-needle (not a metal one) is a good substitute.

*Glass Rod.* This should be six or seven inches long. It is used (i) to stir liquids, (ii) to transfer a liquid from one vessel to another (p. 27), and (iii) to transfer a precipitate from a beaker to a filter-paper. For the last purpose about one inch of the end of the rod is covered with rubber tubing. As a substitute for a glass rod use a length of thick knitting-needle of the bone variety or an old tooth-brush with the bristles cut off.

*Glass Tube.* A short glass tube is useful when you want to add only one or two drops of liquid to a vessel. A fountain-pen filler with a small rubber bulb on the end serves quite well.

*Glass Tubing.* This costs a penny a foot, and can usually be bought already cut into foot lengths. About two yards will be required. The common size used for connecting apparatus has an external diameter of 7 mm., but one or two lengths of a slightly larger size (8 mm.) will prove useful, particularly in glass-blowing.

*Rubber Tubing.* Rubber tubing is used for connecting pieces of glass tubing in fitting up apparatus. If you buy a foot of rubber tubing, costing about 5d., you can cut it into lengths about an inch and a half long as required. You should make sure that the tubing is of a suitable size. It should fit without difficulty on to the glass tubing, but it should not be possible to slide the latter about inside the rubber tubing. You can fit rubber tubing on to a glass tube more easily if the end of the glass tube is first wetted. The sizes commonly used have an internal diameter or 'bore' of  $\frac{3}{16}$  in. and  $\frac{1}{4}$  in.

*Corks.* It is not necessary to buy these except in special cases. Save corks from empty medicine bottles, etc.

*Cork-borers.* These can sometimes be bought in sets of three (costing about 2s. 6d.), which include all the sizes likely to be required. If cork-borers are not available a hole can be made

through a cork by means of a hot steel knitting-needle as described at p. 29.

*Rubber Stoppers.* A rubber stopper fits more tightly into a tube or flask than an ordinary cork and is not porous. It is usually used in preparing gases, but is not absolutely necessary. A rubber stopper already bored can be bought for about 4d., but care should be taken that it is the correct size for the flask or tube for which it is intended.

*Wood Spills.* These are extremely useful in many experiments. Most tobacconists stock wood spills but thin strips of wood from some kinds of match-boxes serve for most purposes.

**Other Apparatus.** You may find additional small items of apparatus desirable as you proceed with your work. Thus you may wish to have a waste-box or tin into which used filter-papers, spills, etc., can be dropped. A dry cloth and a damp cloth might be kept handy. Apparatus needed specially for the preparation of gases is described in Chapter VIII.

### A CHEMISTRY CABINET

As you build up your stock of chemicals and apparatus you will be faced sooner or later with the problem of where to keep them. It is very undesirable that your materials should be left all jumbled together in a box or drawer. You will want to be in a position to lay your hands on any particular chemical or piece of apparatus when it is required.

If you are lucky and have a room all to yourself you will probably be able to fix up some simple shelves on which bottles (properly labelled) can be placed. If, like the author, you are compelled to do your experiments in the kitchen, when it is not being used for domestic purposes, you will need some form of cabinet which can be used for storing materials and which can be brought out easily when required. Instructions are given below for constructing the simple Chemistry cabinet by which the author solved his own storage problem (see Plate 1). Any boy can make this cabinet without special skill in woodwork, but in case of difficulty you might, perhaps, let your father help you!

The essential materials are a wooden box (without a lid), some thin strips of wood or laths, four small hinges, a few screw-eyes or screw-hooks, some string, a few small nails, a hammer, and a saw. The size of the box depends on the size of cabinet desired, but a suitable size is 18 in. long, 10 to 12 in. broad, and 10 to 12 in. high. The box should not be so heavy that it cannot be carried about easily.

First saw down the two long sides of the box, as shown by the

dotted lines in Fig. 5 (a), and detach the two sides. Then nail three pieces of wood of different heights to each of the two remaining sides, so that pieces of similar height face each other across the box (Fig. 5 (b)). Leave a space of about quarter of an inch between the uprights. If you have available only thin strips of wood, place a

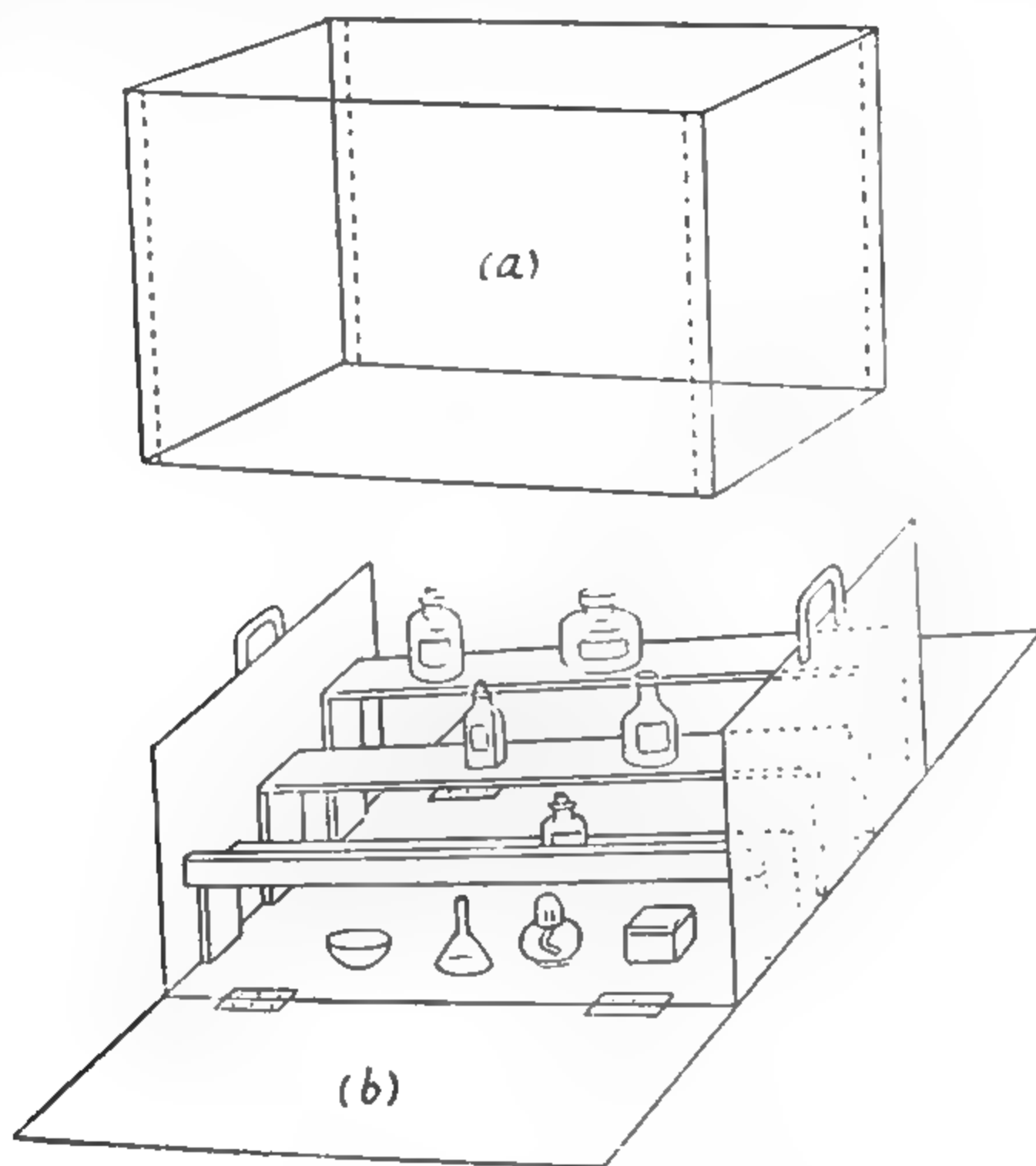


FIG. 5. A CHEMISTRY CABINET

corresponding strip on the *outside* of the box and nail through the box into this. Drive in sufficient nails to make each upright firm. The latter should measure about 2 in. across the top, so, if your strips of wood are narrow, it may be necessary to nail two strips together side by side.

Next saw off several lengths of wood strip to fit from the top of each upright to the corresponding one across the box. Fasten these lengths down with small nails on the tops of the uprights, so that you get three platforms of different heights.

Nail further strips along the side of each upright and across the box, so that the edge of the top strip projects slightly above the edge of the platform. This prevents bottles from sliding forward off the

platform. If an extra strip or two is nailed to the sides of the two back uprights, the bottles are also prevented from sliding backward. (These extra strips are omitted in the diagram for the sake of clearness.)

Attach each of the two loose sides to the bottom of the box by hinges, as shown. Insert screw-hooks in the top corners of the loose and fixed sides on the outside so that loops of string can be used to close the cabinet when the loose sides are drawn up. Finally make two handles for the cabinet by means of screw-eyes and some thick string.

You will now possess a cabinet which can be carried about very easily. Your bottles of solid chemicals, arranged in alphabetical order of their labels, can be kept always on the shelves. In case of accidents, it is better to keep bottles containing liquids in the space at the front of the cabinet on the bottom of the box. The space behind the shelves is used for storing apparatus, such as beakers, test-tube rack, funnels, etc.

## CHAPTER II

### *Simple Operations. Glass-working*

Just as there is a right and a wrong way of making a fire or mending a bicycle puncture, so there is a right and wrong way of doing most of the little operations which make up a chemical experiment. The correct way is the way that chemists after long experience have found to work best. By doing things in the correct way you will save time and materials and avoid disappointing results in your experiments. Although your apparatus may be largely home-made, it is still possible for you to do most of your work in the proper manner (or, as we say, to have a good technique) and thus become a good practical chemist. The chief point to watch is attention to small things. That is why we now describe some of the simple operations which are used over and over again in Chemistry.

#### SIMPLE OPERATIONS

##### *Powdering a Substance*

Sometimes when you buy chemicals you will find that they are in rather large lumps, which makes them difficult to handle and wasteful to use. Usually a substance is powdered by grinding it in a mortar with a pestle (see p. 116). If these articles are not available, put the lumpy material between double folds of thick brown paper on a newspaper and take it out of doors. Crush the lumps with a large, clean stone or other heavy object. Afterwards transfer the powdered substance to a bottle.

##### *Cleaning Test-tubes*

It is usually easier to clean test-tubes immediately after they have been used. First shake a little water in the tube to remove as much material as possible. Then work a wet test-tube brush, or its substitute (p. 21), up and down the tube (this should be done gently to avoid poking the brush through the bottom of the tube). If this treatment does not remove all the substance, fill the tube with warm water and leave it for a time. Then try the shaking and test-tube brush again.

Occasionally special treatment may be required. Working a little sand or soil up and down the tube with a wet test-tube brush is often successful in obstinate cases or the deposit may be loosened

25. Acc. No: 837

with a knitting-needle pushed into the tube. Greasy or oily tubes are readily cleaned by shaking warm soapy water or washing-soda solution in the tube. There is no satisfactory way of cleaning a tube in some cases—for example, when sulphur has been melted in it—and the only thing to do is to throw away the tube.

### *Making a Solution*

There is no point generally in making very strong solutions. For most solutions a strength of about one teaspoonful of powdered substance to a cupful or beakerful of water is suitable. When only a small amount of solution is needed use a saltspoonful of the chemical to half a test-tubeful of water.

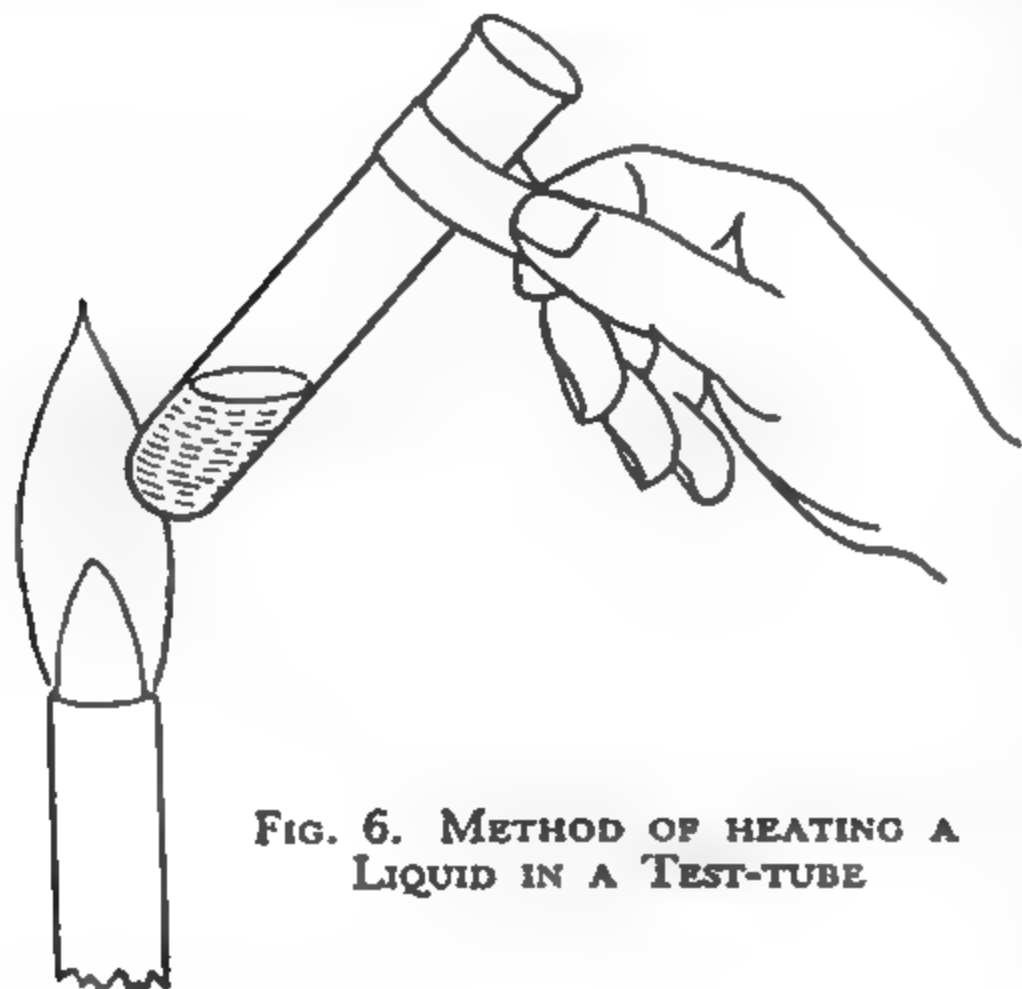


FIG. 6. METHOD OF HEATING A LIQUID IN A TEST-TUBE

Some chemicals dissolve in water more readily than others. Salt and washing-soda are very soluble, baking-soda is moderately soluble, slaked lime slightly soluble, and charcoal is insoluble. A chemical dissolves more easily when it is in the form of powder

than when it is in lumps. Usually substances dissolve to a greater extent in hot water than in cold water, and they also dissolve more quickly.

Solutions of very soluble substances can be made simply by shaking or stirring the powdered substance with cold water. If the substance does not dissolve readily in the cold, heat must be applied. In this case put the water into the beaker or test-tube first and then add the solid. This will prevent the latter from caking, which may result in cracking of the beaker or tube when heat is applied. The beaker and its contents should be warmed on a gauze over a tripod (p. 19), although if you do not possess these you can warm directly over a *very small* flame providing you move the beaker about well.

When you wish to heat a liquid in a test-tube, make a paper holder and hold the top of the tube in this. Make sure that the outside of the tube is dry. Use a flame which is just non-luminous—that is, non-yellow—and not more than two inches high. Warm the tube by moving it about well in the flame. If the liquid begins to boil, carry on with the heating in the edge of the flame (Fig. 6).

This will prevent the liquid from spurting out of the tube. As a precaution, hold the tube pointing away from your face and with your wrist turned well over, so that if the liquid does spurt it does not come out on to your fingers.

Never put your thumb or finger over the end of the tube to shake after you have been heating. The liquid is almost certain to spurt when you take your thumb or finger away.

If your substance does not all dissolve on heating, it will usually be necessary to filter the liquid so as to obtain a clear solution. This operation is described in the next section.

### *Filtering*

Fold a filter-paper across the middle and then across the middle again (Fig. 7 (a) and (b)). Open the paper out so that it looks like

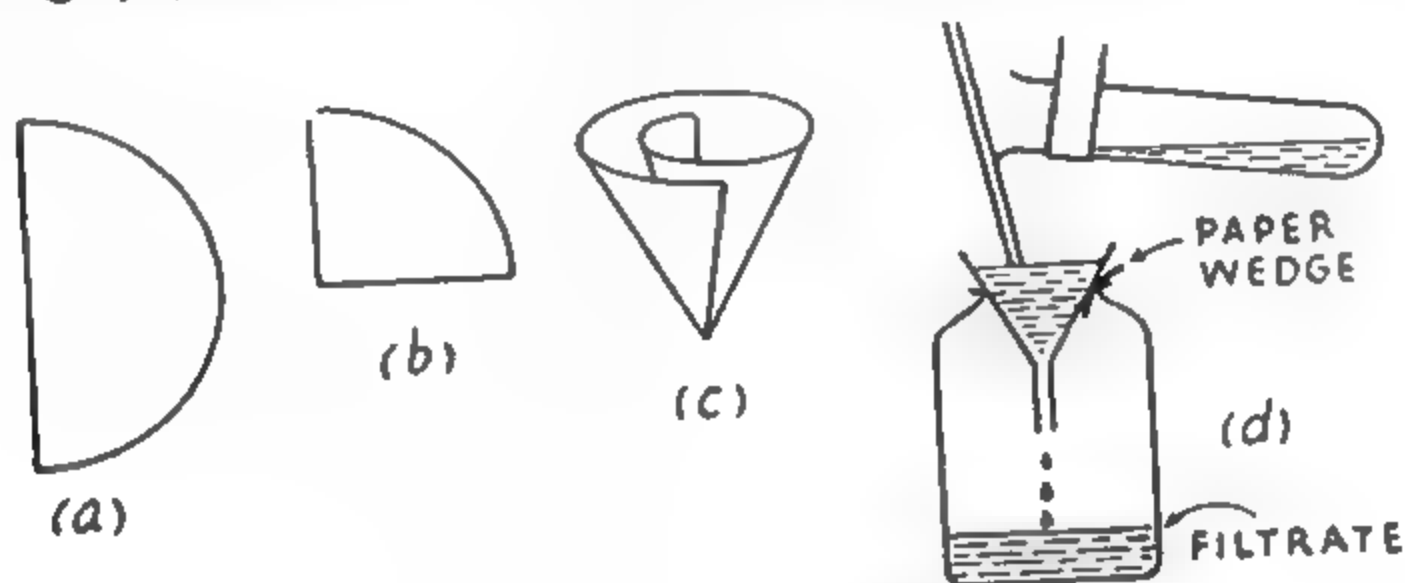


FIG. 7. HOW TO FILTER A LIQUID

a cone (Fig. 7 (c)). Fit the paper into a funnel and let a few drops of water from the tap fall into the paper so that it becomes wet. Gently press the paper against the glass so that the air between the paper and glass is squeezed out. This speeds up the filtering. Put the funnel into the neck of a clean empty jam-jar. Insert a paper wedge between the side of the funnel and the neck of the jar so that a space is left for air to escape from the jar (Fig. 7 (d)). This again quickens filtering.

Transfer the liquid to the filter-paper by running it down a glass rod, or its substitute (p. 21). This method should always be used when transferring a liquid from one vessel to another, as it prevents spilling and splashing. Do not fill the filter-paper to the top with liquid, but leave a gap of about half an inch between the top of the liquid and the top of the filter-paper. The liquid which passes through the filter-paper into the jar below is called the 'filtrate.'

The filtrate obtained should be a perfectly clear liquid. Sometimes when a solution is made from a very fine powder it is still cloudy after filtering. It can usually be made clear either by filtering it



again through the same filter-paper or by letting it run through a double filter—that is, two filter-papers folded together.

**Filtering without Filter-paper.** This can be done by wedging a small plug of cotton-wool about the size of a pea in the neck of the funnel.

**Filtering without a Funnel.** Sooner or later in cleaning your test-tubes you will probably make a small hole through the bottom of one of them. Such a tube can be used for filtering by pushing a plug of cotton-wool about one inch long down to the bottom of the tube. The liquid to be filtered is simply poured into the test-tube

and the filtrate runs out through the hole at the bottom.

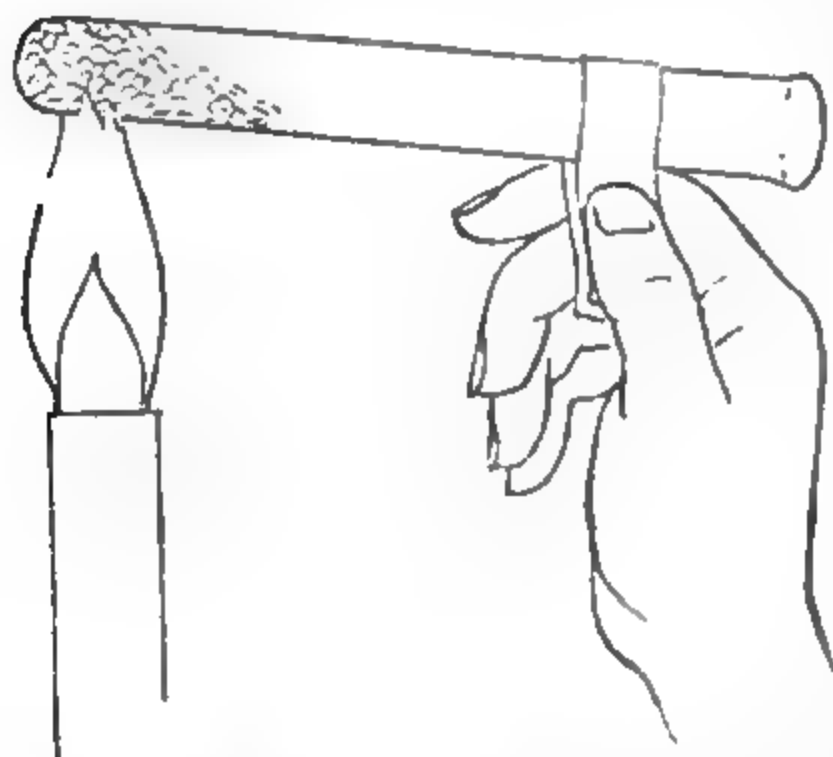


FIG. 8. METHOD OF HEATING A SOLID IN A TEST-TUBE

### *Heating a Solid Substance in a Test-tube*

The test-tube used for heating a solid chemical should be dry. The quickest way to dry a wet tube is to twist a small piece of cotton-wool round the end of a long stick or wood spill and work it up and down the tube two or three times. If this is repeated with another piece of cotton-wool the tube will be dry enough for heating.

Again hold the test-tube in a paper holder, but this time hold it so that it slopes down slightly towards the open end (Fig. 8). The reason for this is that when many substances are heated they give off steam, which condenses in the cooler part of the tube. If the tube is not sloping, the water formed tends to run back on to the hot glass and crack the tube. Place a saucer or evaporating-dish below the end of the tube to catch any drops of liquid which fall from the tube.

Warm the tube very gently at first over a small flame and move the tube about well in the flame. You can safely heat more strongly when the tube has become hot, but keep the tube in a sloping position. If the substance in the tube melts while you are heating, tip the tube up gradually so that the melted substance does not run out of the open end. Do not heat the tube so strongly that the glass begins to melt. When you wish to heat a substance very strongly you should put it into a hard-glass tube, an ignition-tube (p. 34), or a metal screw-cap.

When you have finished heating allow the tube to cool by laying it down on a gauze or asbestos mat.

*Heating a Solid Substance in a Metal Screw-cap*

In a laboratory chemicals are often heated strongly by placing them in a crucible on a pipe-clay triangle. Metal screw-caps from ink bottles, etc., serve the same purpose quite well and have the advantage of not cracking. They should not measure more than one inch across. The screw-cap is held by the sides in a pair of pincers or pliers. Before a screw-cap is used for heating a substance the cork or paper inset should be removed and the paint or lacquer burnt off by heating in a medium flame.

*Fitting and boring Corks*

In setting up apparatus for some of the larger experiments, such as the preparation of gases, it is often necessary to fit a cork into a test-tube or flask and pass a glass tube through the cork. This involves boring a hole through the cork. (Rubber stoppers should always be bought already bored.)

Select a cork which is in good condition and preferably one which is slightly too large rather than too small. A cork which is too large can be made smaller by putting it on a bare floor and rolling it a few times under your foot. It should then fit the tube or flask tightly.

For boring the cork choose a borer which is slightly smaller than the glass tube which is to be passed through the cork. Hold the cork in one hand and screw the borer into the *narrow* end of the cork. Wetting the end of the borer makes the job easier. Hold the cork so that the borer will not pass through the cork and into the palm of the hand. Do not bore right through the cork, because this will leave a jagged hole at the top. When a slight bulge shows at the top, withdraw the borer and screw it in from the top to complete the hole. Remove the cut-out cylinder of cork inside the borer with the metal rod which is usually provided (or use a knitting-needle).

It is difficult to make cork-borers at home. If you do not possess any you can still make a hole through a cork with a steel knitting-needle or piece of copper wire. Holding the needle or wire in a pair of pliers, heat the end in a hot Bunsen flame or a fire until it is red hot. Starting from the narrow end of the cork, burn a hole through the cork, re-heating the needle or wire as necessary. The hole can be widened until the glass tube will pass through. As this method of 'boring' a cork is rather smelly, it is advisable to use it only when you have the room to yourself!

*Passing a Glass Tube through a Cork*

Before you attempt to push the tube through the cork the glass at both ends of the tube should have been rounded off (p. 31) so

that there are no sharp edges. Wet the end of the tube which is to go through the cork. This makes the passage of the tube much easier by reducing friction. Hold the cork in one hand, with the top outward, and with the other hand hold the tube *near the end which is to be inserted* (Fig. 9). Screw the tube into the opening in the top of the cork until it just appears at the other end.

When you are inserting a right-angled piece of tubing through a cork you must on no account hold the tube at the bend and use the arm of the right-angle as a lever. The glass will almost certainly snap, and you may cut your hand badly. If you have difficulty in screwing the tube through the cork after wetting the glass, you must make the hole larger. This is usually done with a round, or rat-tail, file.

### *Loosening a Tight Stopper or Lid*

If any of your bottles have glass stoppers or metal screw-caps you will find that these occasionally stick and you cannot open the bottle.

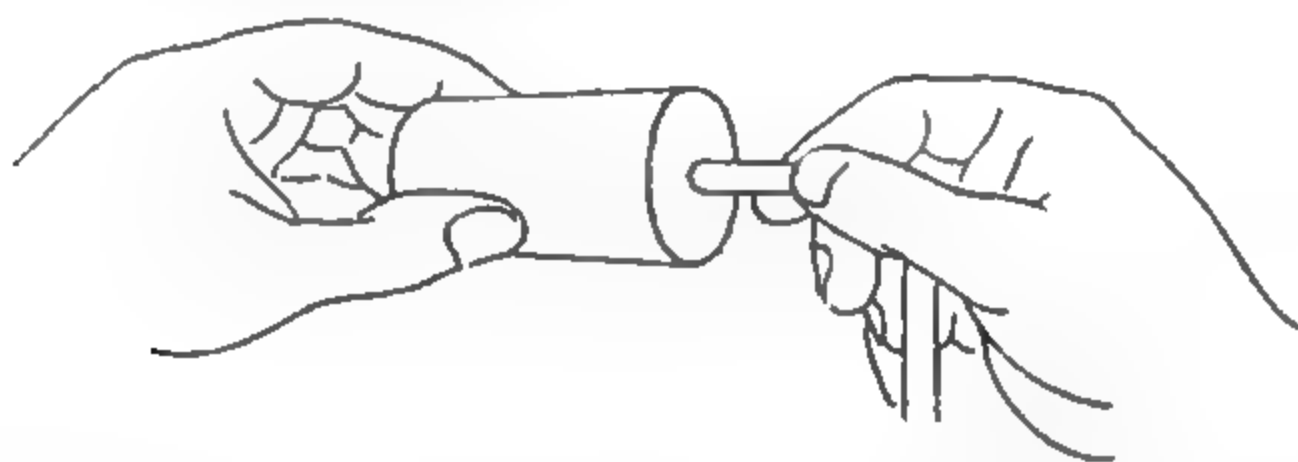


FIG. 9. THE RIGHT WAY TO PASS A TUBE THROUGH A CORK

Usually the difficulty is easily overcome, but sometimes obstinate cases arise. The following is a list of the remedies which should be tried, in the order given:

(i) Tap the stopper on opposite sides with a piece of wood or the back of a penknife while pressing the thumb of the hand holding the bottle against the opposite side of the stopper. The latter precaution is to prevent the stopper from being knocked off.

(ii) Soak a cloth in hot (not boiling) water and wrap it round the neck of the bottle (for a glass stopper) or round the metal screw-cap. Alternatively, allow hot water to drip on from the tap. Follow this up by tapping as described previously.

(iii) Warm the neck of the bottle or the screw-cap over a candle or taper flame and then try tapping again.

(iv) Apply a few drops of glycerine or vinegar around the neck of the bottle and leave it for a few hours.

(v) Turn the bottle upside down in a cup half full of cold water and leave it standing for a while.

## GLASS-WORKING

It is a great advantage to be able to carry out a few simple operations with glass tubing, as you can then extend your work beyond mere test-tube experiments. The chief operations required, which are now described, are well within the powers of the amateur with a little practice. There are two important precautions to observe in glass-working:

(i) Have a metal gauze or asbestos mat handy on which hot glass can be laid.

(ii) Never pick up glass until you have made sure that it is cool enough not to burn your fingers.

*Cutting Glass Tubing*

For this a three-cornered file is required. Make a fairly deep scratch on the tubing by pushing the file smartly across the glass

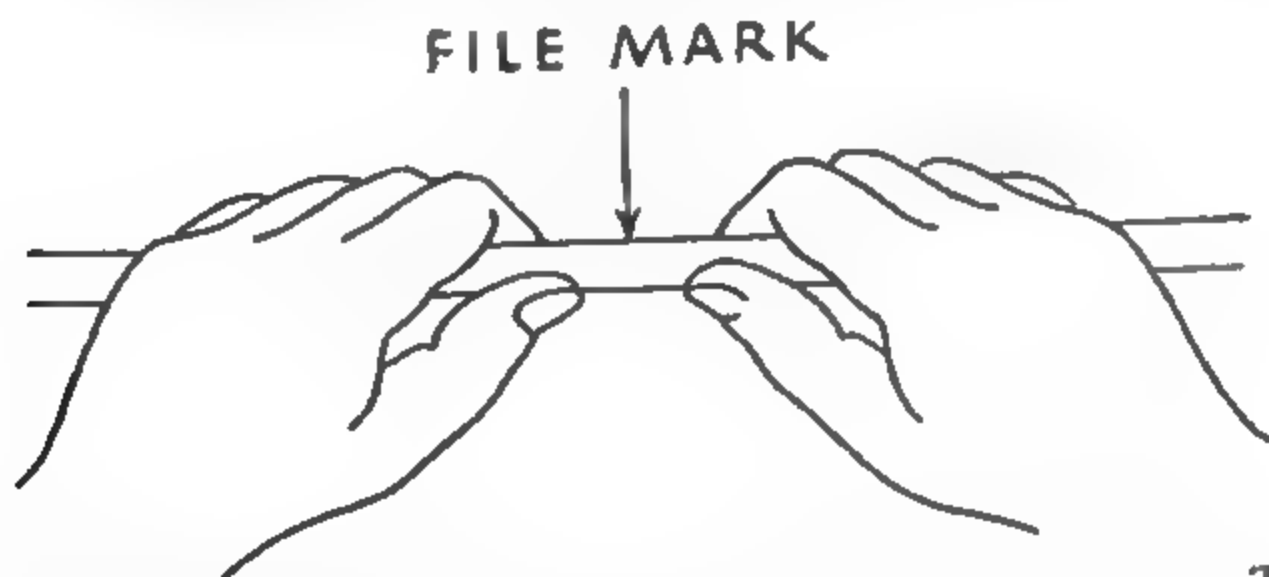


FIG. 10. METHOD OF HOLDING THE GLASS IN CUTTING A TUBE

two or three times. Do not 'saw' the glass, as the aim is to start a crack, not to grind away a lot of the glass. Hold the tubing in both hands with the file mark away from you and place both thumbs fairly close together on the side of the tubing opposite to the file mark. Try to bend the ends of the tubing towards you by pressing your thumbs away from you. The glass should break cleanly at the file mark. *Do not use great force.* If the tubing does not break easily, make the file mark deeper and try again.

The above method of cutting glass is only used for the narrow glass tubing used in setting up apparatus. Wider tubing (over  $\frac{1}{4}$  in. diameter) is cut by the method described later. When the tubing has been cut, the sharp edges should be rounded off at once as described in the next section.

*Rounding off Sharp Edges*

Sharp edges on glass tubing are dangerous and should be removed before the glass is used. Hold the tubing with the sharp edge in the

side of a small flame for a few minutes. The glass will melt slightly and the sharp edge will disappear. Allow the end of the tube to cool before inserting it into a cork or piece of rubber tubing.

### *To cut the Top off a Broken Test-tube*

Two methods of cutting wide glass tubes are now described. They can be tried out on test-tubes which have become chipped at the top. Broken tubes of this kind are dangerous to use in experiments unless the broken part is removed.

**Method 1.** Make a file mark on the broken tube at least half an inch below the broken part, and draw a line with a piece

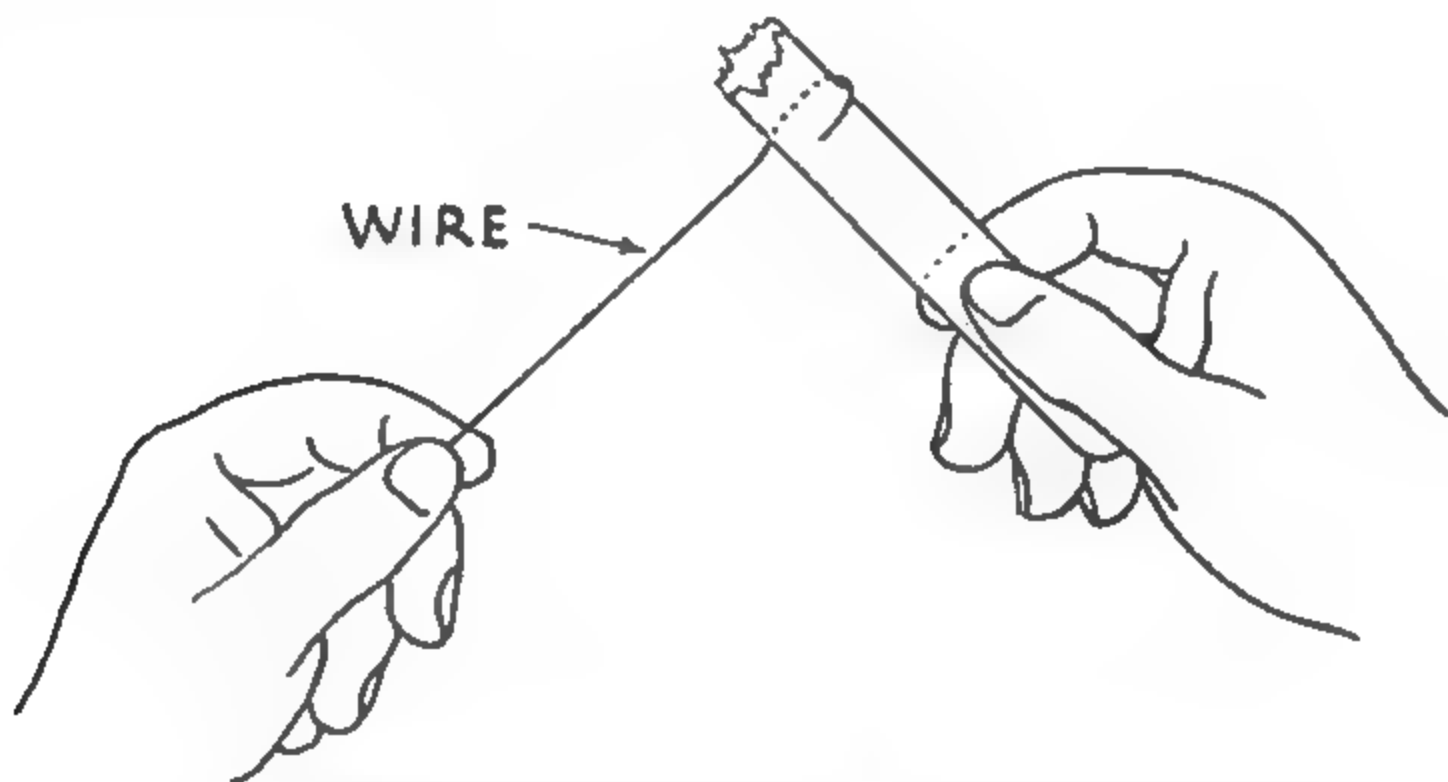


FIG. 11. CUTTING THE END FROM A BROKEN TEST-TUBE

of chalk round the tube where you wish the separation to take place. Obtain a short length (about three inches) of ordinary narrow glass tubing. Heat one end of the tubing at first gently and then more strongly (turn the tubing round in the flame) until a blob of red hot glass is formed at the end. Lightly touch the *end* of the file mark on the broken test-tube with the blob of hot glass. You will hear a small crack start round the tube. Reheat the blob and touch the glass with it just *beyond* the crack along the chalk line. The crack will jump towards the hot blob. Continue this process until the crack has travelled right round the test-tube. A slight tap or pull will now detach the broken part of the tube.

**Method 2.** This method is perhaps not as reliable as Method 1, but it is quicker. Make a semicircular loop at the end of a length of iron or copper wire so that the loop just fits round the tube (Fig. 11). Make a file mark on the tube about a quarter of an inch long. Again mark a chalk line round the tube.

Heat the loop in a flame until the metal is red hot. Lay the test-tube in the loop so that the end of the loop just touches the file mark.



SOME HOME-MADE CHEMICAL APPARATUS

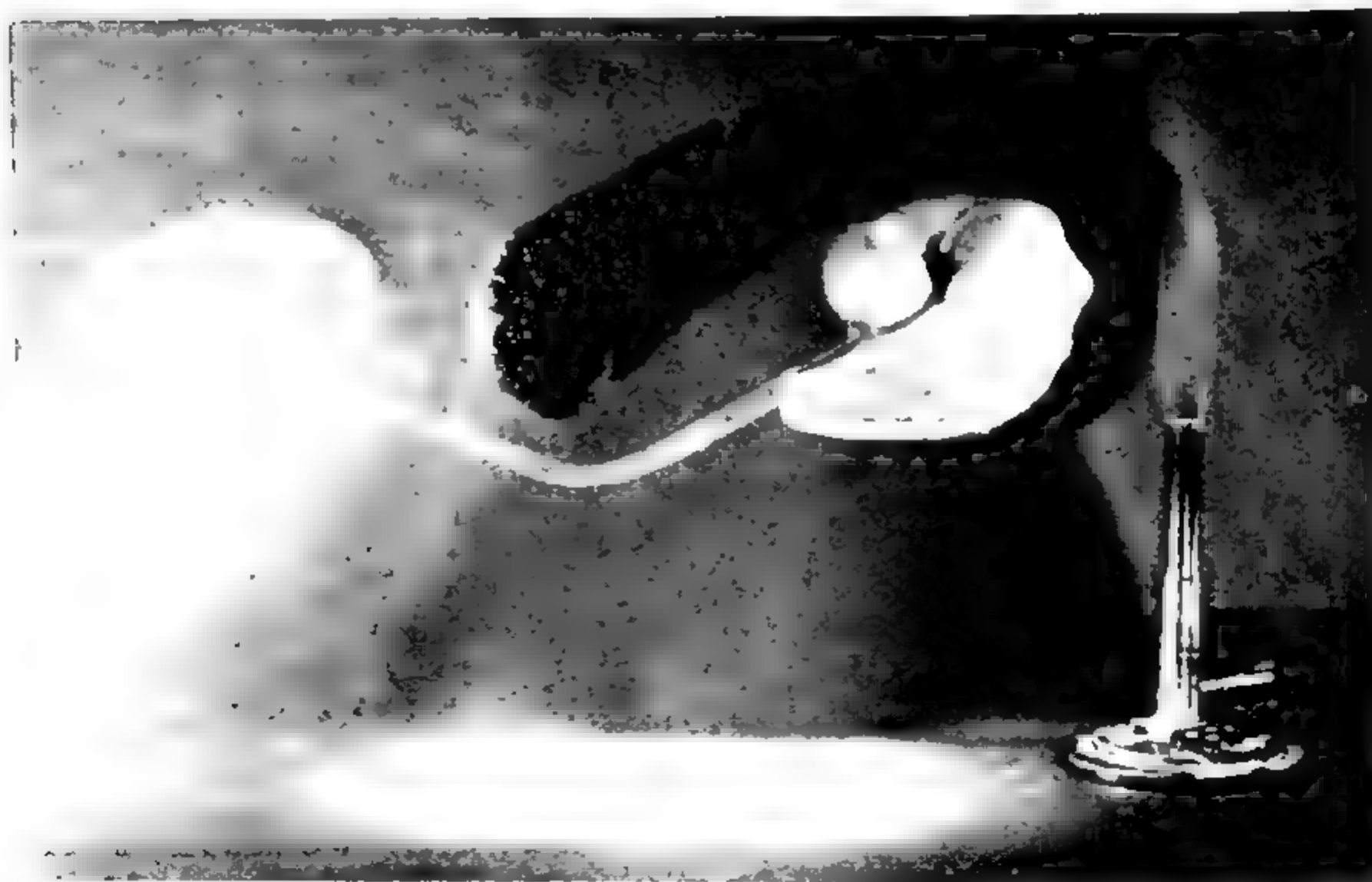


A HOME-MADE CHEMISTRY CABINET





FIGURE 1. STILL LIFE WITH BONES.





You will hear a crack jumping around the tube where the metal touches the glass. Immediately you hear the crack, turn the test-tube round in the loop. The crack will probably travel completely round the tube. If necessary, reheat the loop and again lay the test-tube in it, and turn the tube round. When the crack has circled the tube a slight tap or pull will be sufficient to separate the two parts. If you have difficulty in starting the crack, make the file mark a little longer and deeper.

**Completing the New Tube.** Whether you have used Method 1 or Method 2 for cutting off the broken portion, the remaining tube will need further treatment before it is put into use. The sharp edge left on the glass should be rounded off in the side of a flame as previously described. If a test-tube is to pour satisfactorily it should have a rim. It will be an even better pourer if you make a spout on it, as in the case of a beaker.

To make a new rim, obtain a piece of wood about the size of an egg. Trim the wood with a knife so that one end is made into the shape of a cone like the bottom part of a spinning-top, and so that about half the cone will enter the end of the tube. Hold the cut portion in a flame for a few seconds to char the surface. Alternatively you can cut a lump of charcoal to the required shape. Heat the open end of the new tube at first gently and then more strongly until the glass softens. Hold the wood cone in one hand and press the mouth of the tube lightly on to the cone with the other hand. The softened glass will be pressed outwards, and when the tube is withdrawn after a few seconds it will be found to have a rim.

A spout is made on the tube by means of a three-cornered file. Heat the rim of the tube at the desired point until the glass becomes soft, and also warm the end of the file. Then draw the edge of the file across the softened edge of the tube at an angle of forty-five degrees. This will produce the required spout. If you wish to deepen the spout, repeat the operation.

### *Bending Glass Tubing*

To bend glass tubing properly a special burner, known as the 'batwing' burner, is required. This gives a very broad, luminous flame. However, with practice fairly satisfactory bending can be carried out with a Bunsen burner or even a methylated spirit burner. Photographs which illustrate the method of working are shown in Plate 2.

The tube to be bent should be at least six or seven inches long. Adjust the flame of the Bunsen burner so that it is fairly hot, but not roaring. Hold the tube between your thumbs and first fingers, as shown in Plate 2, the thumbs being above, and the fingers below

the tubing. Heat the glass in the top part of the flame. While heating keep the glass rolling round between the fingers and thumbs, and also keep it moving a little across the flame so that the tube is heated over a distance of two or three inches.

After a time the flame will turn yellow, which is a sign that the glass is beginning to soften. Gradually the glass will become red hot, but do not be in a hurry to get on with the job. Keep the tube in the flame until it becomes so soft that it is difficult to maintain the rolling movement. Then take the tube out of the flame and bend the ends *upward* until a bend of sufficient amount is obtained.

### *To make an Ignition-tube from Glass Tubing*

Ignition-tubes are used for heating substances strongly, and to economize in the use of test-tubes and hard-glass tubes. Generally

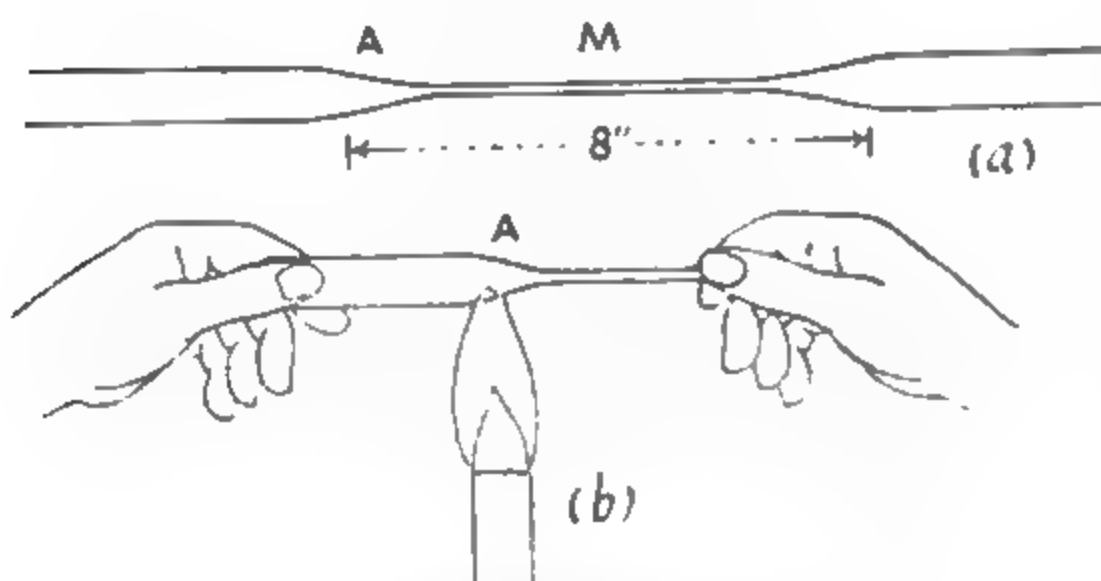


FIG. 12. STAGES IN THE MAKING OF AN IGNITION-TUBE

they can be used only once and then have to be thrown away. A Bunsen burner is required to construct them. The glass-tubing should preferably be somewhat wider (8 mm.) than that used for glass-bending.

Take a piece of glass tubing about eight inches long and heat it exactly as described in

the last section—that is, as if you were going to bend the tubing. When the glass has got to the red-hot, sagging stage withdraw it from the flame and, after waiting a couple of seconds, draw the hands outward, so that the heated portion is drawn out into a long thin tube about eight inches long (Fig. 12 (a)). The usual mistake of the beginner is to take the tube out of the flame too soon, so that either only a very short, thin tube is formed or the tube parts in the middle.

Allow the glass to cool and then, by means of a file, cut the thin tube at the middle, M, which gives you two similar portions. Reheat the first portion in a hot flame at the shoulder A, holding the glass by the two ends and rolling it round in the flame (Fig. 12 (b)). When the glass is red hot and soft draw off the thin part from the shoulder, A. This leaves a short tube which is closed at one end. It probably leaves also a thick blob of glass at the end of the tube where the thin portion was drawn away. This thick blob should be removed by heating the end of a pair of pliers and the end of the

tube at the same time in the flame and then drawing away the blob with the pliers. A few seconds' reheating of the tube completes the job. Leave the tube to cool on a gauze or sheet of asbestos.

A second ignition-tube can be made from the other portion of glass tubing drawn off, or it can be used for the blowing of a bulb, as described in the next section.

*A most important precaution is to gather together carefully all the small pieces of glass left over from the experiment and to throw them away. They are dangerous if left lying about.*

### *Blowing a Bulb at the End of a Tube*

To blow a bulb on an ignition-tube, made as described above, heat the end of the tube at first gently and then strongly. Hold the tube with the end pointing downward, and turn it round in the flame. When the glass is red hot remove it from the flame and, holding the tube in a vertical position between the first two fingers of your right hand and left hand, blow down it fairly strongly.

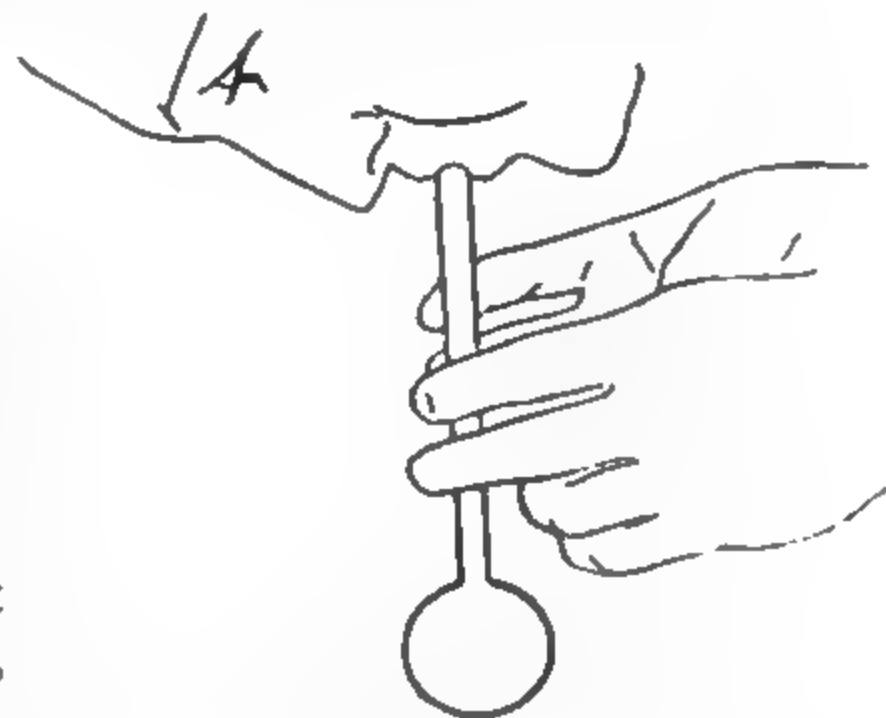


FIG. 13. METHOD OF HOLDING THE TUBE IN BLOWING A BULB

While blowing roll the tube between the fingers. This should cause a small, even bulb to form at the end of the tube. If you blow too strongly, the bulb may swell out and burst. To make the bulb larger, repeat the heating and blowing two or three times. The bulb when finished should measure about three-quarters of an inch across.

Your bulb-tube can be used, like an ignition-tube, for the heating of substances, or you can make it into a magnifying glass as now described.

### *Making a Magnifying Glass from a Bulb-tube*

This is done by filling the bulb-tube with water. Owing to the narrowness of the tube, however, you cannot just pour water into the tube, for the air inside cannot escape. To overcome the difficulty, warm the bulb over a small flame and then dip the open end of the tube into a cupful of water. The air inside the tube will contract on cooling, and water will be sucked up the tube and into the bulb. By repeating this operation a few times the bulb and most of the tube will become filled with water. Plug the open end of the tube with a little modelling clay.

When small objects are viewed through the water-filled bulb they are magnified considerably. This home-made magnifying glass should be kept and used for examining crystals, the preparation of which is described later in the book.

### *Making a Jet on a Glass Tube*

For some experiments, such as the Fountain Experiment (p. 143), it is desirable to know how to draw a tube out into a jet.



FIG. 14. A DROPPING-TUBE

Take a length of glass tubing about eight inches long and proceed as if you were going to make an ignition-tube—that is, heat the middle of the tube while rolling it between the fingers. Limit the heating, however, to about an inch in the middle of the tube. When the glass is soft and sagging remove the tube from the flame, count three, and then draw out the tube so that a thin portion about an inch long is formed. Allow the glass to cool and, by means of a file, cut the tube in the middle of the thin portion. Round off the ends of both parts, but take care not to seal the end of the jets.

You will now have two tubes with jets. These can be used for the experiments described in the next two sections.

### *A Handy Dropping-tube*

This is a useful article to have when you want to add single drops of a liquid to a test-tube.

Fit a piece of rubber tubing, about an inch and a half long over the wider end of the jet-tube. Close the other end of the rubber with a bit of glass rod, knitting-needle, or stub of a pencil. Dip the

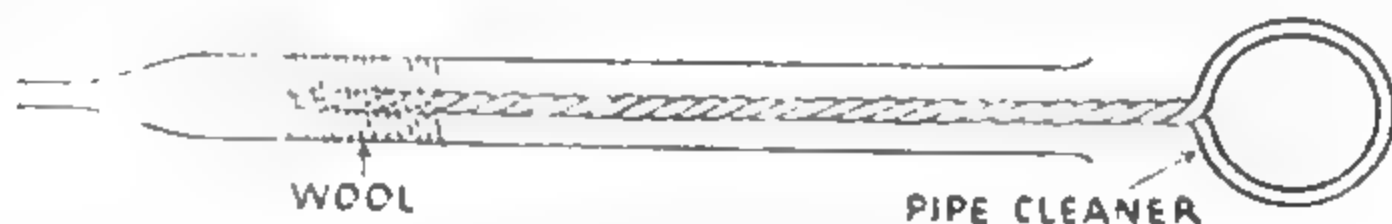


FIG. 15. A SYRINGE

narrow end of the tube below the surface of a liquid and squeeze the rubber. Air is expelled from the tube, and when the pressure on the rubber is released the liquid is drawn into the tube.

### *A Home-made Syringe*

A jet-tube can also be used to make a small syringe or water-squirt. Bend a pipe-cleaner in the middle and twist the two halves round each other as shown in Fig. 15, leaving a small loop at the

middle. Wind some thin wool tightly, but as evenly as possible, round the end to a length of about an inch. Obtain just sufficient thickness of wool to allow the end of the plunger to pass into the jet-tube. Tie the ends of the wool. You will now have a small but quite efficient syringe.

## CHAPTER III

### *Simple Experiments*

THIS chapter describes some easy but interesting experiments which can be performed by the beginner in Chemistry. One of the common mistakes made by the beginner is to use far more of his materials than is needed to carry out an experiment. This not only results in the chemicals being wasted, but often prevents an experiment from being as successful as it should be. In the following experiments the amounts which should be used are indicated. The measurements for solid (powdered) chemicals are usually given in terms of a saltspoonful or a teaspoonful. It should be understood that these refer to a *level* spoonful. Liquid measures are given by the depth of liquid to be taken in an ordinary (5 in.  $\times$   $\frac{1}{8}$  in.) test-tube.

Before starting an experiment make sure that you have all the materials required in front of you. It is often a nuisance to have to interrupt an experiment because something is missing. Read the instructions carefully and follow them as closely as possible.

#### *Crystallizing out Boracic Acid*

Boracic acid (chemists call it boric acid) is a white solid substance which is very soluble in hot water, but has only a small solubility in cold water.

Measure out a teaspoonful of boracic acid into an egg-cup. Warm half a test-tubeful of water over a small flame, holding the tube in a paper holder. When the water begins to boil remove the tube from the flame, add a little of the boracic acid by means of a saltspoon, and continue boiling. The substance will dissolve. Continue adding the boracic acid and boiling until the whole of the substance has been dissolved. Now allow the tube to cool. A beautiful shower of fine white crystals will form as the liquid cools. If the crystals are filtered and the filter-paper opened out to dry, the boracic acid can be replaced in your stock-bottle for further use.

#### *Crystallizing out Copper Sulphate, Alum, etc.*

Copper sulphate, or blue vitriol, differs from boracic acid in being very soluble, even in cold water. We therefore use a different method for crystallizing it.

Take half a test-tubeful of warm, but not hot, water. Add a

saltspoonful of powdered copper sulphate, put your thumb over the end of the tube, and shake it gently until the powder has dissolved. Add another saltspoonful of the chemical and shake again. Keep on adding copper sulphate and shaking until no more will dissolve in the water and a layer of the powder settles on the bottom of the tube. You now have a 'saturated' solution of the chemical. Wash your hands, because copper sulphate is poisonous.

Filter the liquid (or pour it off if it is quite clear) into an evaporating-dish or any small, open dish. Put the dish aside for a few hours, and leave it undisturbed. Blue diamond-shaped crystals will form in the dish. Pour away any liquid left, and scrape the crystals with a wood spill on to a piece of blotting-paper or filter-paper to dry them. Complete the drying by placing the blotting-paper and crystals on an old newspaper and leaving them for a time in a warm place, such as the bottom of the airing-cupboard. Put the dry crystals back into your stock of copper sulphate.

This experiment can be repeated with many other chemicals besides copper sulphate. Alum, washing-soda, magnesium sulphate (Epsom salts), and ferrous sulphate (green vitriol) are suitable substances to use. In the case of ferrous sulphate you must add one or two drops of dilute sulphuric acid to the water or the solution will turn brown and spoil (see p. 74). The growing of big crystals is described in Chapter VII.

### *Invisible Writing*

There are dozens of recipes for invisible inks. Some of the simplest are given here, although others which depend on treatment with special chemicals to develop them are described later in the book (see pp. 79, 90, and 182). For the writing to be invisible it should be done on unglazed paper, like drawing-paper.

**Brown Writing.** Dissolve a teaspoonful of sugar in half a test-tubeful of water, by shaking. Dip a wood spill or small paint-brush in the solution and write your name on paper. Warm the paper near the fire or by holding the paper about six inches above a small flame. Your name will appear in brown letters. Milk, lemon-juice, onion-juice, and even saliva can be used instead of the sugar solution.

**Black Writing.** Dissolve one saltspoonful of alum in about an inch of water in a test-tube and use this in the same way as the sugar solution. Dilute sulphuric acid, sodium bisulphate solution, and copper sulphate solution can also be used.

**Blue Writing.** One of the best known invisible inks is made from red cobalt chloride crystals. Dissolve one saltspoonful of the crystals in one inch of water in a test-tube. This gives a pale pink solution



which is almost colourless when it is used for writing. If pink note-paper is used, the writing is quite invisible. When warmed, it shows up in a brilliant blue colour. The writing can be made to disappear by breathing on it, but it will appear again if the paper is warmed once more.

**Transparent Writing.** Write on paper with a small piece of candle or wax. The writing is quite invisible until the paper is warmed.

An unusual and little-known recipe for invisible ink is the following. Put into a test-tube one drop of any kind of oil and half an inch of strong household ammonia. Fill up the tube with water and shake it well. Dip a small paint-brush into the liquid and write on paper. Allow the writing to dry, when it will become invisible. The writing is made to appear by dipping the paper into water, but the writing will disappear again when the paper is dry. This can be repeated as often as desired. The liquid should always be well shaken before use.

### *Indicators*

Indicators are substances used in Chemistry to find out whether a liquid is an acid or an alkali. They have different colours in acids and alkalis. If the liquid, like water, is neither an acid nor an alkali, it is said to be 'neutral.'

Some well-known indicators are litmus, phenolphthalein, Congo red, and logwood extract. The last of these is a dark red liquid obtained when logwood chips (which are often included in Chemistry sets) are boiled with water. Logwood is got from a certain kind of tree growing in warm climates, and litmus from a plant, while phenolphthalein and Congo red are made from coal-tar. The colours which are produced in acids and alkalis are shown in the following table.

INDICATOR	IN ACID	IN ALKALI
Litmus	Red	Blue
Logwood	Yellow	Purple
Phenolphthalein	Colourless	Pink
Congo red	Blue	Red

Put a few drops of the following solutions, in turn, into an egg-cup (wash the egg-cup after each test): vinegar, lemon-juice, citric acid, alum solution. Test the liquids with small pieces of blue litmus paper or one drop of any of the other indicators.

Similarly test in an egg-cup solutions of the following alkalis: washing-soda, lime-water, and dilute ammonia. This time use red litmus paper for testing.

**A Home-made Indicator.** Cut two or three slices from a fresh (unboiled) beetroot. Put the slices into a beaker or small saucepan with half a tumblerful of water. Boil the water for five minutes, when a dark red solution will have formed. Allow the liquid to cool and pour it off from the beetroot. Test the same liquids as in the previous experiment with a few drops of the red solution. This indicator has a red colour with acids and a yellowish-green colour with alkalis.

Red cabbage and many other plants can also be used for making indicators. Some of these are described at p. 145.

### *Neutralizing an Acid with an Alkali*

Dissolve one saltspoonful of citric or tartaric acid crystals in two inches of water in a test-tube and pour the solution into an evaporating-dish or egg-cup. Add to the liquid a piece of blue litmus paper (which at once turns red). Put some dilute ammonia or washing-soda solution (p. 17) into a test-tube and add this, one or two drops at a time, to the acid solution. Stir the liquid round each time after adding the alkali. Stop adding the alkali when the litmus paper just turns blue again. You have now neutralized the acid with the alkali.

Neutralization of an acid by means of an alkali (usually ammonia) is used to render an acid harmless when it has been spilled on clothes. The alkali destroys the corrosive properties of the acid.

### *Copper-plating Iron*

Dip the blade of a penknife or a clean nail into copper sulphate solution. The blade will quickly become covered with a layer of copper. The copper can be removed by drying the blade and rubbing it with emery-paper.

### *Decolorizing Iodine*

Make a weak solution of 'hypo' (sodium thiosulphate) by dissolving a saltspoonful of the chemical in a test-tubeful of water. Put a few drops of iodine solution into another test-tube and add the 'hypo' solution to it one or two drops at a time. The colour of the iodine will vanish.

The colour can be restored by adding to the test-tube a few drops of very weak acidified bleaching fluid. Use only two or three drops of the fluid to half a test-tubeful of water and add a saltspoonful of citric acid or a few drops of dilute sulphuric acid.

*The Curious Action of Starch and Iodine*

Heat half a test-tubeful of water until it boils. Add a small pinch of powdered starch and continue boiling for a few moments. Cool the solution by running cold water over the tube. In another test-tube put a few drops of iodine solution and add to it a few drops of the cold starch solution. The liquid which results looks black, but actually it is a very deep blue colour. This can be shown by filling the tube with water and holding it up to the light.

Pour away some of the blue liquid, leaving the tube about half full. Warm it over a small flame. In a few moments the blue colour will disappear. Now cool the tube under the tap. The colour will return. This can be repeated as often as you like.

The blue colour which iodine gives with starch is a very sensitive test, and it is said that one part of iodine in five million parts of water can be detected by this action. Chemists often use the test the other way round as a means of recognizing the presence of starch in various kinds of foods. You can carry out this test as follows. Boil one or two small pieces of potato with a little water in a beaker or small saucepan for a few minutes. Pour off the liquid into a test-tube, cool it under the tap, and add a drop or two of iodine solution. A blue colour will show that the potato contained starch.

*Blowing Lime-water Milky*

Put an inch or two of clear lime-water into a test-tube. Blow gently through the liquid by means of a glass tube or drinking-straw. The lime-water will turn a milky colour. This action is caused by the carbon dioxide gas in your breath.

*Blowing a Red Liquid Colourless*

Add one drop of washing-soda (sodium carbonate) solution to a test-tubeful of water and, after shaking, pour away all except one inch of the liquid. Now add a drop of phenolphthalein solution. This will give a red solution. Blow through the liquid for a few minutes. The red colour will disappear completely. The reason for this is that the carbon dioxide in your breath is an acid gas and neutralizes the alkali of the washing-soda solution.

*Home-made Health Salts. Testing for Carbon Dioxide*

Health salts of the fizzy kind usually contain sodium bicarbonate (baking-soda) and an acid substance such as tartaric acid or citric acid. This mixture can easily be made at home. You should not drink the mixture, however, as your ingredients may not be pure and safe.

Mix together in a dry egg-cup a teaspoonful of baking-soda and

a teaspoonful of tartaric or citric acid. Add some of the mixture to about an inch of water in a tumbler. The fizzing, or effervescence, as it is called in Chemistry, is caused by the giving off of carbon dioxide gas.

To show that carbon dioxide gas is given off in the above action, put about an inch of lime-water into a test-tube. Put some of the health salts mixture into another tube and add a few drops of water. When the fizzing starts put the mouths of the two tubes together, as shown in Fig. 16, so that the lip of the lime-water tube comes below the lip of the other tube. Carbon dioxide is a heavy gas, and it will roll down into the lime-water tube. When the effervescence stops put your thumb over the end of the lime-water tube and shake

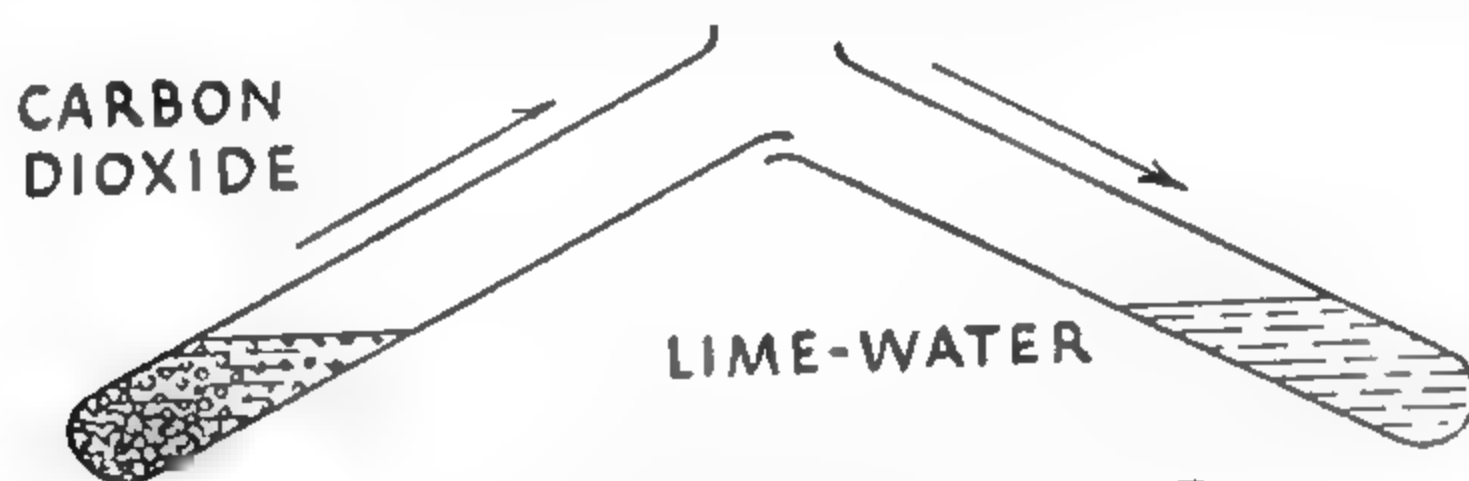


FIG. 16. METHOD OF TESTING FOR CARBON DIOXIDE

the tube. The lime-water will turn milky showing that carbon dioxide has been given off.

#### *Carbon Dioxide from Chalk or Washing-soda*

Put a little chalk or washing-soda into a test-tube and add a few drops of vinegar (which contains acetic acid) or some citric or tartaric acid solution. Test for the giving off of carbon dioxide as described above. It should be noted that blackboard chalk is not real chalk and it does not give off carbon dioxide when treated with an acid. The chemical name of real chalk is calcium carbonate, and that of washing-soda is sodium carbonate. Any substance called a carbonate yields carbon dioxide with an acid.

Calcium carbonate is usually present in egg-shells, whiting (Blanco), tooth-pastes, and tooth-powders. Another form of calcium carbonate is marble. Washing-soda is one of the common ingredients of washing-powders. If any of these materials are available, you might test them to see whether they give off carbon dioxide when they are treated with an acid.

#### *Dyeing Easter-eggs*

In some parts of the country it is the custom at Easter to boil and dye eggs to use in various ceremonies. The dyeing can be

easily carried out at home. Ordinary coloured chemicals are not suitable for this purpose, because some of them are poisonous. The following dyeing materials can be used, and produce the colours indicated: parsley (green), cochineal (red), beetroot (red), coffee (brown). Simply add a little of the material to the water in which the eggs are being boiled.

### *Drawing Water through a Potato*

Slice one end off a potato and scoop out a hole about an inch deep in the exposed end. Put a teaspoonful of sugar into the hole and stand the potato with the cut end at the top in a beaker or cup, as shown in Fig. 17. Fill the beaker or cup about half full of water and leave it on a shelf.

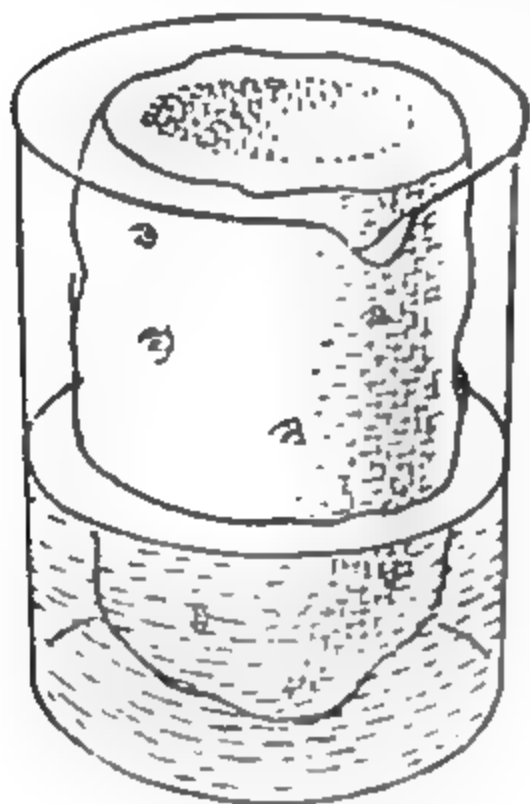


FIG. 17. A POTATO EXPERIMENT

In a few hours the hole will have filled up with water drawn through the potato by the sugar. The sugar, of course, will have dissolved in the water.

This experiment illustrates one of the methods by which water passes from the soil through the cells of a plant. It occurs only with living cells. If the experiment is repeated with a potato which has been immersed in boiling water for a few minutes to kill the cells, it will be found that no water is drawn into the hole through the potato.

### *Carbon Dioxide from Flowers and Leaves*

Here is a little scientific investigation which you can carry out. The problem is to discover how light affects the giving out of carbon dioxide gas by flowers and leaves.

Obtain four empty jam-jars with lids. Into two of the jars put one or two flowers (any kind will do, providing they are not very small). In the other two jars place sprigs of mint, lettuce leaves, or any kind of green leaves. Leave one jar containing flowers and one containing green leaves on a window-shelf in daylight. Put the other two jars in a dark cupboard.

After about two hours test the jars from the window-shelf by quickly taking out the flowers and leaves (do not turn the jars over) and pouring in a little lime-water. Put the lids on and shake the jars. Similarly test the two jars which were left in the dark to see if they now contain carbon dioxide. Your results should agree with the following:

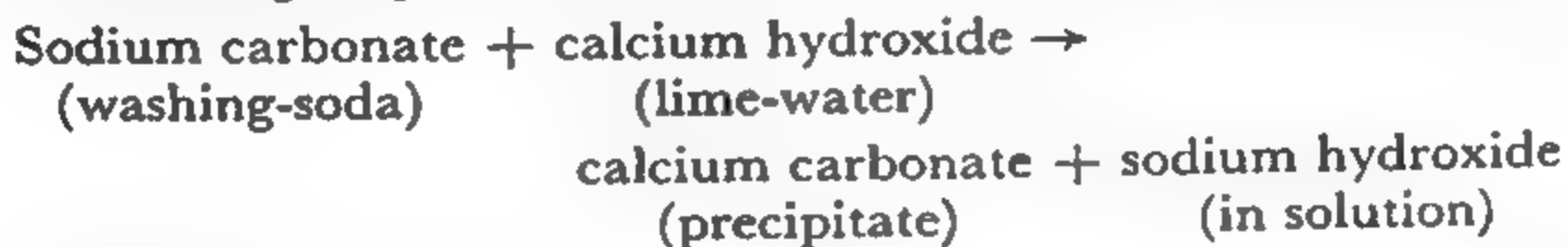
—	LEFT IN DAYLIGHT	LEFT IN DARK
FLOWERS . . .	Carbon dioxide	Carbon dioxide
GREEN LEAVES . . .	No carbon dioxide	Carbon dioxide

Flowers give out carbon dioxide all the time, whether in daylight or darkness. Leaves and the other green parts of plants, however, only give out carbon dioxide in the dark. In daylight they actually take in carbon dioxide from the air and turn it into oxygen, a gas which we require for breathing.

### *Making Precipitates*

It often happens that when a solution of one chemical is added to a solution of another chemical a solid substance is formed. This is called 'precipitating' the solid substance, and the latter, when it is formed in this way, is referred to as a 'precipitate.' Precipitates are usually obtained in the form of a fine powder, although sometimes they are seen as a jelly-like (gelatinous) material.

Add a little washing-soda solution to some clear lime-water in a test-tube. Immediately a white precipitate of chalk, or calcium carbonate, will be formed. The manner in which the precipitate is produced is rather interesting. The chemical action which occurs is an 'exchange of partners' process. It can be represented as follows:



The chalk is precipitated because it is insoluble in water. The sodium hydroxide, which is also formed, is not precipitated, because it is soluble in water. The proper chemical name for the 'exchange of partners' action is 'double decomposition.'

COLOUR OF PRECIPITATE	CHEMICALS
White	Alum + ammonia
Pink	Cobalt chloride + sodium carbonate
Brown	Iron alum + ammonia
Black <sup>1</sup>	'Hypo' + copper sulphate
Green	Ferrous sulphate + ammonia
Blue	Sodium carbonate + copper sulphate

<sup>1</sup> The precipitate is formed only when the mixture is boiled.



By adding solutions of the right chemicals to each other you can obtain various colours of precipitates. The table given on p. 45 shows what chemicals to use to obtain coloured precipitates.

### *A Beautiful Royal Blue Colour*

The bottles of coloured liquids which chemists use to adorn their shop windows often include one containing a deep blue solution. This striking colour can be made as follows. Dissolve one saltspoonful of blue vitriol (copper sulphate) in half a test-tubeful of water. Add dilute ammonia solution, drop by drop, to the cold liquid and mix thoroughly. At first a light blue precipitate will be obtained. Keep adding the ammonia and shaking. The precipitate will disappear and a deep royal blue liquid will be formed.

### *Proving that a Liquid really is Water*

You might think that you could always tell whether or not a liquid was water by its appearance or by tasting it and smelling it. There are plenty of colourless liquids besides water, however, and it is not always possible to apply the tests of tasting and smelling. In this case we apply a chemical test to find whether the liquid is water or contains water.

Gently warm a little powdered copper sulphate on a clean tin-lid or in a metal screw-cap held in a pair of pincers or pliers. The powder will lose its blue colour and turn greyish-white. Allow the substance to cool and divide it into two parts. First drop on to one part of the white powder a drop of methylated spirit or liquid paraffin. Nothing will happen. Now add a drop of water to the other part of the powder. The powder will at once turn blue again and steam will be given off.

Another test for water is carried out with a solution of cobalt chloride. Dissolve a saltspoonful of this chemical in an inch of water in a test-tube. Pour a few drops of the red solution on to a filter-paper, and dry the filter-paper by holding it in front of the fire or over a small flame. The paper will turn a bright blue colour. Test the paper first with a drop of methylated spirit or liquid paraffin and then with a drop of water. The latter will restore the light pink colour of the cobalt chloride, but the other liquids will have no effect.

### *A Strange Property of 'Hypo'*

Usually when a solid substance is heated sufficiently it melts and then if the melted substance is cooled it becomes solid again. 'Hypo' (sodium thiosulphate) is an exception to this rule if it is treated in the right way.

Put two or three drops of water and about an inch of 'hypo'

crystals into a test-tube and warm the tube gently over a very small flame, moving the tube about over the flame. When the crystals have dissolved remove the tube from the flame and put a small plug of cotton-wool into the top of the tube. This will keep out dust that is in the air. Allow the tube to cool, when it will be found that the contents are still liquid (if dust is allowed to enter the tube the liquid may solidify before it is cold).

Now remove the plug of cotton-wool and add a tiny speck of solid 'hypo' to the tube. If the tube is gently shaken the liquid will immediately turn into a mass of solid crystals and the tube will become hot.

This experiment can also be carried out with sodium sulphate (Glauber's salt).

### *How Iron can be Burned*

To burn iron it must be in the form of fine particles (iron filings) or wire (steel wool). Sprinkle a few iron filings into a Bunsen flame. The filings will burn and produce a fine shower of sparks. If you sprinkle the iron filings from an old pepper-pot into the flame and have the room in darkness you will obtain a striking but perfectly safe firework display.

Steel wool is often used for cleaning pans at home. To burn well it should be very fine. Hold a little of the steel wool in a pair of pliers and heat it for a moment in a flame. It will burn with a bright glow. When iron burns it combines with the oxygen of the air and forms a greyish-black oxide of iron, which has the chemical formula  $\text{Fe}_3\text{O}_4$ .

### *Coloured Flames*

These are made by introducing small amounts of various chemicals into a non-luminous (non-yellow) flame, and give very pretty effects when the experiment is carried out in a darkened room. Ordinary salt, boracic acid, chloride of lime, and copper sulphate are suitable chemicals to use. Coloured flames are also given by chemicals containing potassium or strontium, if you have any of these in your Chemistry set. To carry out the tests you will require a few spent matches or wood spills.

Wet the ends of the matches or spills and pick up a little of the chemicals on the wet ends. Introduce them into the side of a flame and different colours will be imparted to the flame, as follows:

Common salt	Orange-yellow
Boracic acid	Green
Chloride of lime	Red
Copper sulphate	Greenish-blue
Potassium compounds	Lilac or violet
Strontium compounds	Crimson

In the last three cases the colour obtained will be more brilliant if a little sal-ammoniac (ammonium chloride) is mixed with the chemical.

If there is another person in the room when you are doing the experiment with common salt it is interesting to observe his face. The orange-yellow flame will give his face a bloodless and ghost-like appearance. The same effect is produced by the sodium-vapour lamps which are used to light the streets in some of our towns and cities.

### *An Inflammable Gas from Sugar*

This is a suitable experiment to perform with a bulb-tube if you have made one as described at p. 35. Otherwise you can use an ordinary test-tube.

Fill the bulb of the bulb-tube not more than half full of sugar or put half an inch of sugar into the test-tube. Hold the tube in a paper holder so that it slopes down slightly (see Fig. 8), and place a saucer below the open end to catch any liquid which falls from the tube.

Heat the sugar gently at first and then more strongly. The sugar will melt and turn first brown and then black. Drops of a brown liquid will be formed in the cooler part of the tube and will run down into the saucer. When the sugar turns black put a lighted spill to the end of the tube. The gas which is being given off will ignite and burn with a yellow flame. The black substance left in the tube after the experiment is a form of carbon called 'sugar charcoal.' The liquid which collects in the saucer is water coloured by tarry impurities. It can be tested with white copper sulphate or blue cobalt chloride paper made as described at p. 46.

In this experiment you obtain from one substance, sugar, at least three other substances—sugar charcoal, water, and an inflammable gas. When a single chemical splits up and gives a number of other substances it is said to 'decompose' and the chemical action is called 'decomposition.'

### *An Experiment with Sugar and Baking-soda*

Mix together on a piece of paper a saltspoonful of sugar and an equal amount of baking-soda (sodium bicarbonate). Put the mixture on to a tin-lid and flatten the heap out with the back of a spoon. Hold the lid in a pair of pincers or pliers and heat the mixture over a medium Bunsen flame. In a few moments a puffy black pillar will rise up from the mixture to a height of two or three inches and present a very curious appearance. The pillar consists largely of sugar charcoal blown up by carbon dioxide gas which is given off from the

baking-soda. The black substance is very light and can easily be blown off the lid.

### *Burning of a Candle*

Take a clean, dry jam-jar, hold it upside down, and put into it a lighted candle as shown in Fig. 18. Notice that the glass becomes dim owing to a film of dew deposited on it. In a short while the flame will go out. Again light the candle and put it into the jar. Again it will go out. Now turn the jar over, quickly pour a little lime-water into it, and shake the liquid round. The lime-water will turn milky, showing that carbon dioxide has been produced.

The candle flame goes out because it uses up the oxygen gas in the air which is in the jam-jar. Air consists chiefly of two gases, oxygen and nitrogen, but only one of these, oxygen, takes any part in burning. The oxygen combines with the carbon and hydrogen of which the candle is made, and produces carbon dioxide and water respectively.



FIG. 18. BURNING  
A CANDLE IN  
A JAM-JAR

### *Fireproofing*

Paper, wood, and other materials which burn can be rendered fireproof by soaking them in a strong solution of 'hypo' (sodium thiosulphate) or water-glass (sodium silicate). Leave two or three matches soaking in a strong solution of one of these chemicals for an hour or two. Leave also some tissue-paper, cotton-wool, and a few strands of ordinary wool in the solution for a few minutes. Squeeze them out lightly and leave them to dry in a warm place. You will find that the materials which you have treated will not burn when dry.

### *Making the 'Bad Egg' Gas*

The name of this gas, beloved of schoolboys, is sulphuretted hydrogen, or hydrogen sulphide. It can be made from 'hypo' crystals.

Heat a few 'hypo' crystals in a metal screw-cap held in a pair of pincers or pliers. Heat gently at first until the substance has melted and then solidified again. Steam will be given off. With stronger heating the smell of sulphuretted hydrogen will be recognized.

Allow the screw-cap to cool. Moisten the white substance which remains with a few drops of vinegar or any acid solution. A very strong smell of sulphuretted hydrogen will now be noticed. To test for the gas chemically dip a strip of filter-paper in copper sulphate

solution and hold the paper just above the screw-cap. The paper will turn black.

### *How to make Other Gases*

**Oxygen.** The easiest way to make this gas is from hydrogen peroxide. Put half an inch of hydrogen peroxide solution into a test-tube and add a drop or two of green vitriol (ferrous sulphate) solution. The contents of the tube will froth vigorously due to the giving off of oxygen. The gas is colourless and cannot be seen. It is also without smell. Test it by lighting a wood spill, blowing the spill out, and introducing the end while still glowing into the mouth of the test-tube. The spill will light up again.

Another way to make oxygen is by means of bleaching fluid. Put half an inch of the strong fluid into a test-tube and add a few drops of a fairly strong solution of cobalt chloride. A black precipitate will form. Warm the tube gently until frothing starts and then remove the tube from the flame. Oxygen will be given off in abundance. Chloride of lime can be used instead of bleaching fluid.

**Hydrogen.** Put a quarter of an inch of iron filings into a test-tube and just cover them with an acid solution (citric acid, dilute sulphuric acid, sodium bisulphate). Warm the tube gently until frothing starts. Hydrogen is colourless, or invisible. When it is pure it has no smell, but traces of other gases usually make it impure, giving it a rather nasty smell. Test the gas by removing the tube from the flame, putting your thumb over the end of the tube, counting five, and then applying a lighted spill at the end of the tube. There will be a sharp 'pop' as the inflammable gas explodes.

*Note.* It is extremely dangerous to explode any quantity of hydrogen greater than a test-tubeful, and it should never be attempted.

**Ammonia.** Put two saltspoonfuls of sal-ammoniac (ammonium chloride) into a test-tube and add an inch of washing-soda (sodium carbonate) solution. Warm the tube. Test the ammonia gas by smelling it cautiously and by means of wet red litmus paper. Ammonia is an alkali.

### *Removing Oxygen from Air with Iron Filings*

It has been mentioned previously (p. 49) that the burning of substances depends on the presence of oxygen gas in the air. The oxygen in a jam-jar can be removed by allowing iron filings to rust in the jar.

Dissolve two teaspoonfuls of ordinary salt in a cupful of water. Swill a little of the solution round in the jam-jar so as to wet the inside thoroughly. Pour the solution out, and sprinkle iron filings

around inside the jar so that they cling to the sides of the jar. Put the jar, mouth downward, in a flat dish or saucer half full of the salt solution and place it on a shelf or in a cupboard where it can be left undisturbed for two or three days. The liquid will start rising into the jam-jar, because the oxygen in the air inside is being removed by the iron filings to form rust. Rust is an impure red oxide of iron, which has the chemical formula  $\text{Fe}_2\text{O}_3$ . Add more salt solution to the dish or saucer each day to restore the original level.

At the end of about three days the liquid will stop rising in the jar. This will occur when all the oxygen has been removed. The liquid should then be about one-fifth of the way up the jar, because one-fifth of the air is oxygen. The remaining four-fifths consists chiefly of nitrogen gas. Test the nitrogen by sliding a piece of stiff cardboard over the mouth of the jar, turning the jar over, and putting a lighted taper or spill into it. The light will be extinguished. Now that the oxygen has been used up the remaining nitrogen will not support combustion—that is, let things burn in it.

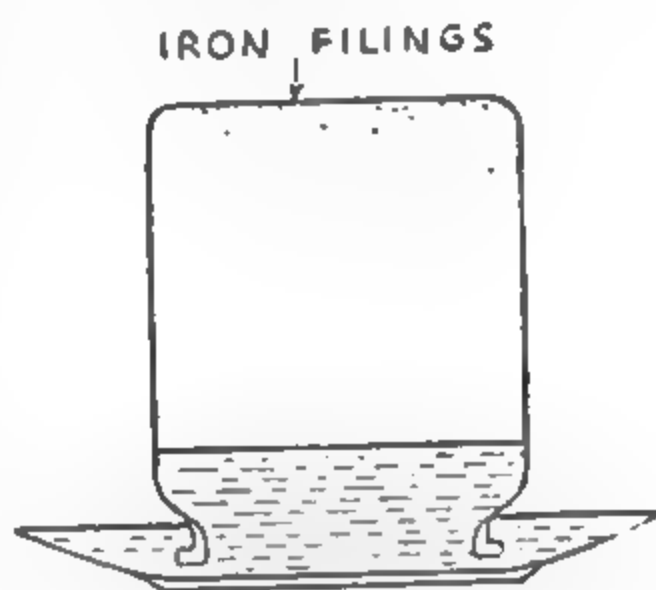


FIG. 19. APPARATUS FOR REMOVING OXYGEN FROM AIR

### *Make Your Own Ink-eradicator*

For this you require two solutions, one of citric acid or tartaric acid and one of bleaching fluid, such as Chlorox.

Dissolve two saltspoonfuls of the acid in one inch of water in a test-tube and transfer the solution to an egg-cup. Put half an inch of bleaching fluid into a test-tube and fill up the tube to half-way with water. Transfer this solution to another egg-cup. Using a glass rod or wood spill, moisten the writing-ink with the acid solution and leave it standing for a couple of minutes. Then blot the writing and moisten it with the second solution. The ink will slowly disappear.

To prevent damage to the paper put a little more of the acid solution on the paper where it has been moistened with bleaching fluid. Blot the paper and dry it in front of the fire.

If you put the two liquids into small bottles and label them they will be available at any time for removing blots, etc.

### *Making Potash Crystals (an Alkali) from Cigarette Ash*

Collect enough cigarette ash to half fill a test-tube (but do not include any tobacco). Fill the tube with warm water to just over half-way and shake it for a minute. Part of the ash will dissolve. Filter the liquid and collect the filtrate (the liquid which passes



through the filter-paper) in an evaporating-dish. Test the liquid with red litmus paper. The paper will turn blue, showing that an alkali is present. Leave the solution in a warm place to evaporate. White crystals of the alkali called potash (potassium carbonate) will be formed.

Test the product (preferably after mixing it with a little ammonium chloride) by introducing it into a flame on the end of a wet spill. A lilac or violet colour should be imparted to the flame. This is the test for potassium compounds. Also test the crystals with a drop or two of an acid. There should be frothing due to the giving off of carbon dioxide gas. This is the test for a carbonate (p. 43).

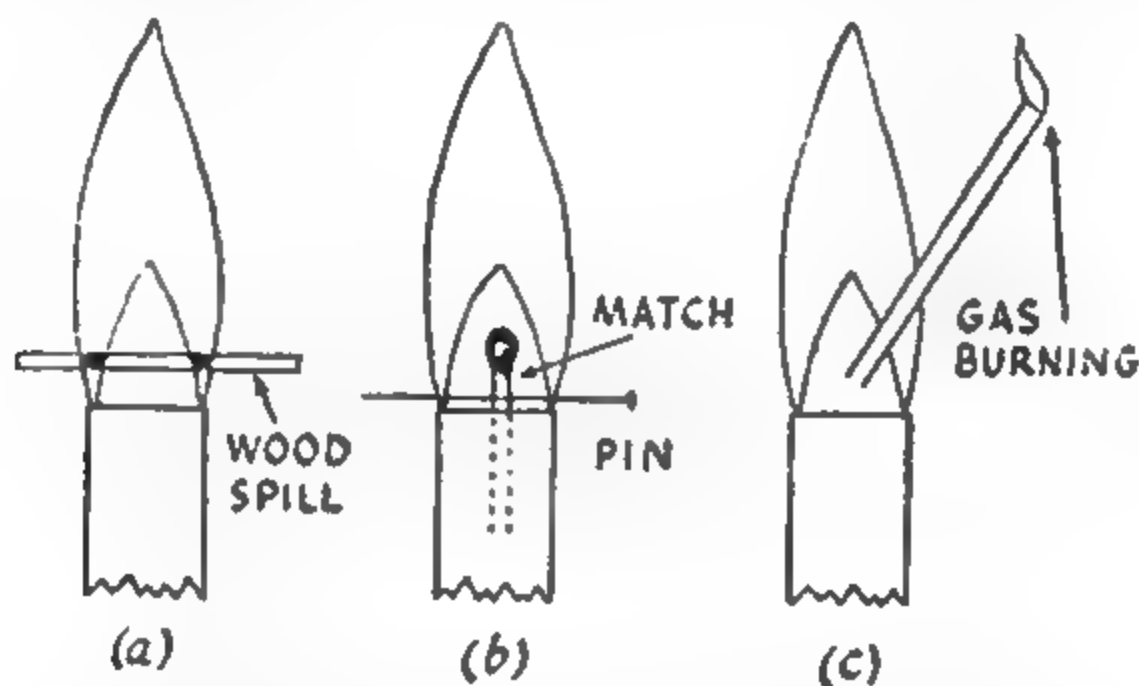


FIG. 20. EXPERIMENTS WITH A BUNSEN BURNER

Potash was one of the earliest alkalis known to mankind. It was obtained by burning wood in pots and washing the white ash left after burning. This explains how the name 'pot-ash' arose.

### *Experiments with a Bunsen Burner*

If you have a Bunsen burner there are a number of interesting experiments which you can do with it as now described.

(i) Turn the gas-tap about half on and have the air-hole of the burner about half open. Hold a wood spill for a second in the middle of the flame and about half an inch above the top of the burner (Fig. 20 (a)). Remove the spill before it catches fire. There will be two scorch-marks where the spill was in the outer part of the flame (as indicated by the shaded portion of the spill in the diagram). Between the two marks the spill will not be burned. This shows that the centre part of the flame is quite cool.

(ii) Pass a pin through the stick of an unlit match about half an inch from the head. Turn the Bunsen flame out and lay the pin across the top of the burner so that the stick is down the barrel and the head of the match directly above the centre of the barrel (Fig. 20 (b)). Now turn the gas full on and light it. If there is no

draught, the match-head will not set on fire, although it is surrounded by burning gas. This again shows the coolness of the inside part of the flame.

(iii) Put the end of a narrow glass tube into the cool, inside part of the flame (Fig. 20 (c) ). Apply a light to the other end of the tube and a small flame will start burning there. This shows that the centre part of a Bunsen flame contains unburned gas. You can move the lower end of the glass tube up and down in the flame and find how far this region of cool, unburned gas extends.

(iv) Unscrew the barrel of the burner (make sure that it is cold first), thus revealing the narrow jet in the base from which the gas issues. Turn on the gas and light it at the jet. The flame will leap high into the air, showing that the gas is rushing out of the jet at great speed. It is the speed of the gas rushing through the jet which causes air to be sucked in through the air-hole when the latter is open.

(v) Replace the barrel of the burner, close the air-hole, and light the gas. Hold a porcelain lid or piece of broken saucer in a pair of pliers and introduce it into the luminous flame for ten seconds. When you withdraw it you will find a black deposit of soot, or carbon, on the porcelain or saucer. A similar result is produced with a candle flame.

Repeat the experiment with the air-hole partly open, so that a non-luminous flame is obtained. There will be no deposit of soot this time. The gases composing coal-gas contain a good deal of carbon, which appears as carbon particles when the air-hole is closed. The particles are rendered white-hot by the heat and thus make the flame luminous. When the air-hole is open the air mixed with the coal-gas burns up the carbon so that no carbon particles are formed.

### *A Simple Sugar Experiment*

Fill a basin with water and when the water has become still, float a match on it. Dip one corner of a sugar cube into the water about half an inch from one end of the match. In a few moments the match will move towards the sugar, and if you move the sugar slowly away the match will follow it. The cause of this curious behaviour is not magnetism, as you might suspect. As the sugar dissolves in the water the heavy solution falls to the bottom of the basin and the surface water flows towards the sugar to replace the descending liquid. The match is merely carried towards the sugar by the surface current. If you colour the lump of sugar with a drop of ink you will see that this explanation is correct.

## CHAPTER IV

### *Experiments with Common Chemicals*

WHAT experiments can I do with so-and-so? This is the kind of question which the keen young chemist armed with a boxful of chemicals asks his elders. In this chapter we describe a great variety of experiments which can be performed with simple, common substances. For the convenience of the reader the names of the substances are arranged in alphabetical order.

Most of the chemicals, which are additional to those mentioned at p. 16, will have to be bought, but many will be found in the kitchen cupboard, the medicine chest, or elsewhere at home. The approximate prices of chemicals are listed at p. 231. In most cases one ounce will be a sufficient quantity to carry out the experiments given in this chapter.

The experiments which follow are easy to perform, but again the experimenter is advised to read the instructions carefully and use the amounts of substances specified. It is generally a good idea to make enough solution of a chemical to do all the experiments described under that chemical. This will save time and will avoid the trouble of constantly preparing fresh solutions.

#### *Alum* (Potash Alum)

*Chemical Name:* potassium aluminium sulphate. *Chemical Formula:*  $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ .

There are several alums, but the name is generally used for potash alum. This is a white crystalline substance, which can be made by mixing together solutions of potassium sulphate and aluminium sulphate and leaving the liquid to crystallize. It dissolves fairly readily in water. The solution is acidic and turns blue litmus red. Alum is sold in the form of styptic pencils for stopping bleeding from small cuts. Industrially it is used as a mordant in dyeing to fix the dye to the cloth (see Simple Dyeing Experiments, p. 139).

Make a solution containing half an inch of alum crystals in two-thirds of a test-tubeful of water and use the solution in the following experiments. Be careful not to spill the acid solution about.

**Making Hydrogen Gas.** Put a saltspoonful of iron filings into a test-tube with half an inch of alum solution and warm the tube gently. When frothing or effervescence begins remove the tube from the flame. Put your thumb over the end, count five, and then

apply a lighted wood spill to the end of the tube. The hydrogen in the tube will explode with a sharp 'pop.'

**Making Carbon Dioxide Gas.** Have ready a test-tube containing an inch of clear lime-water. Into another test-tube put half an inch of baking-soda or washing-soda and just cover it with alum solution. Again there will be effervescence. Test for the carbon dioxide given off with the lime-water tube as described at p. 43.

**Making Aluminium Hydroxide.** A white gelatinous (jelly-like) precipitate of aluminium hydroxide is obtained by adding a solution of an alkali to alum solution. Use half an inch of alum solution and an equal amount of dilute ammonia or washing-soda solution. The precipitate will disappear if a solution of an acid, such as citric or sulphuric acid, is added to the tube and the tube gently shaken.

**Removing Colour from Liquids with Aluminium Hydroxide.** This experiment works well with the common dyes Congo red and cochineal. The latter is used in confectionery to give a pink colour to icing and cakes. The experiment can also be done with blue-black ink or red ink.

Add not more than one drop of the dye solution to an inch of water in a test-tube. Put in about an equal amount of dilute ammonia and then fill up the tube with alum solution. Allow the tube to stand. The aluminium hydroxide which has formed will gradually settle to the bottom of the tube as a coloured jelly, having taken the colour out of the liquid. The results will be seen more clearly if the liquid is filtered.

**Making Alum Crystals.** An interesting method of performing this experiment is now described.

First make a warm, saturated solution of alum by adding three or four teaspoonfuls of the powdered substance to half a cupful of hot water and leaving the substance to dissolve for a few hours in a warm place, such as the bottom of the airing-cupboard or a warm oven. Stir the liquid from time to time to make sure that it becomes saturated. Pour off the warm, saturated solution into a small beaker or jar.

Tie one end of a length of cotton round a wood spill and attach a small weight (*e.g.* a button) to the other end. Suspend the weighted cotton in the liquid as shown in Fig. 21. Leave the beaker or jar overnight in a cool place. Diamond-shaped alum crystals will be deposited on the cotton. The method of growing a large crystal of alum is described in Chapter VII.

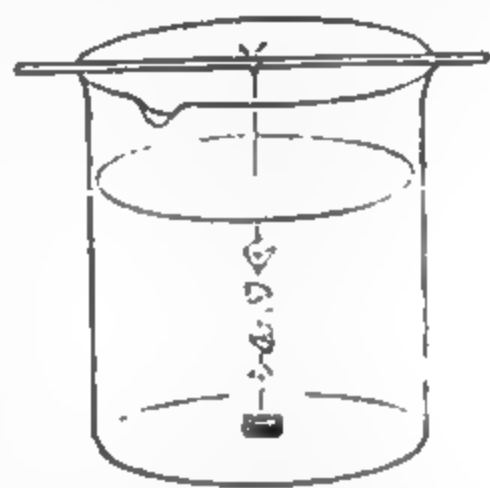


FIG. 21. METHOD OF GROWING ALUM CRYSTALS ON COTTON

The experiments described under Aluminium Sulphate can also be carried out with potash alum.

### *Aluminium*

*Chemical Symbol:* Al.

Aluminium is a metallic element<sup>1</sup>. It is remarkably light and is used for making kettles, saucepans, etc. You can obtain aluminium from milk-bottle tops, tooth-paste tins, etc.

**Making Hydrogen.** Cut half an aluminium milk-bottle top into small pieces. Put the pieces into a test-tube and add a teaspoonful of washing-soda and an inch of water. Hold the tube in a paper holder and warm it over a small flame. When effervescence starts remove the tube from the flame and test for hydrogen with a lighted spill as described at p. 54.

**Action of Acids.** Heat a few small pieces of aluminium with about an inch of dilute sulphuric acid or dilute nitric acid in a test-tube. In either case there will be effervescence due to the giving off of hydrogen from the sulphuric acid or oxides of nitrogen from the nitric acid. It is difficult to get sufficient hydrogen to explode with a lighted spill. A solution of aluminium sulphate or aluminium nitrate will be formed. After heating the metal with the acid for about five minutes allow the tube to cool, and pour off the solution into another test-tube. Add to it about two inches of dilute ammonia solution. A white gelatinous precipitate of aluminium hydroxide will be obtained.

### *Aluminium Sulphate*

*Chemical Formula:*  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ .

This is a white crystalline substance similar in many ways to potash alum (which is partly made from it). It has the advantage, however, of being much more soluble in water than potash alum. Aluminium sulphate is used, along with sodium bicarbonate and a soap-like chemical, in 'foam' fire-extinguishers. It is also used to bring about the settling of small particles of suspended solids in reservoirs and sewage.

**The Foam used in Fire-extinguishers.** Make some warm, but not hot, soapy water and put about an inch of the liquid into a beaker or jam-jar. Shake an inch of baking-soda (sodium bicarbonate) with half a test-tubeful of water for a few seconds and pour it into the soapy water. Now add half a test-tubeful of fairly strong aluminium sulphate solution. A white mass of bubbles will rise in the beaker or jar and look like an ice-cream soda. The foam is very

<sup>1</sup> An element is a substance which cannot be split up into any other substances. Elements are divided into two classes, metals and non-metals. A list of the chief elements, with their chemical symbols, is given at p. 232.

strong and will last for hours. The foam produced by fire-extinguishers forms a 'blanket' over the burning material and shuts out the air (see p. 137).

**Clearing Muddy Water.** Shake an inch of soil with a test-tubeful of water. Pour half of the muddy liquid into a jam-jar and the other half into a second jar. Fill both jars to about half-way with water. Into one jar pour half a test-tubeful of aluminium sulphate solution and then slowly add half a test-tubeful of dilute ammonia or sodium carbonate solution. Stand the treated jar beside the untreated one and leave both undisturbed. In about ten minutes the treated water will appear quite clear, but the untreated water will still be muddy.

**A Test for Aluminium Compounds.** Put one or two drops of red cobalt chloride solution on to a piece of filter-paper or white blotting-paper and then drop on also one or two drops of aluminium sulphate solution. Dry the paper by holding it over a small flame and then set fire to it over a saucer. The ash will be blue. This is a test given by all aluminium compounds in solution.

Aluminium sulphate can also be used for doing the experiments described under Alum. The making of 'ammonia alum' from aluminium sulphate is described at p. 61.

### *Ammonia*

*Chemical Name:* ammonium hydroxide. *Chemical Formula:*  $\text{NH}_4\text{OH}$ .

Ammonia is really an invisible gas, with the chemical formula  $\text{NH}_3$ , but when the gas is dissolved in water (it is very soluble) it forms an alkali with the name and formula given above. Household 'ammonia' is a strong solution of the gas, and is used for cleaning. The familiar choking smell of the liquid is caused by the gas escaping into the air. 'Cloudy ammonia' contains powdered soap in addition to ammonia.

In Chemistry ammonia solution is chiefly used for neutralizing acids and for precipitating the metal compounds known as hydroxides. The latter are produced, usually as jelly-like precipitates, when ammonia is added to solutions of soluble compounds of the metals. Examples are given under Alum, Ferrous Sulphate, Iron Alum, Magnesium Sulphate, and Zinc Sulphate.

Household ammonia is far too strong for most experiments. A dilute solution is made by adding about five parts of water to one of the strong solution.

**Making Ammonium Sulphate by Neutralization.** Put half a test-tubeful of dilute sulphuric acid into an evaporating-dish and add a small piece of red or blue litmus paper (the blue turns red). From a test-tube add dilute ammonia solution, a drop or two at a



time, to the dish, stirring the liquid with a rod or wood spill after each addition. Continue adding the ammonia and stirring until the litmus paper just turns blue. Then remove the litmus paper and leave the dish in a warm place to evaporate. The evaporation can be hastened by gently boiling away about two-thirds of the liquid before leaving it. White crystals of ammonium sulphate will be formed in the dish.

When an acid is neutralized by an alkali a crystalline substance called a 'salt' is formed. Ammonium sulphate is an example of a salt.

### *Ammonium Carbonate*

*Chemical Formula:*  $(\text{NH}_4)_2\text{CO}_3$ .

This is a white powder, and it is fairly soluble in water. The solution is a weak alkali. Ammonium carbonate is used in 'smelling-salts,' which are used sometimes to revive a fainting person. The effect is caused by sniffing the ammonia gas given off from the ammonium carbonate in the bottle.

**Decomposing Ammonium Carbonate.** When heated ammonium carbonate decomposes completely into three gases or vapours, steam, ammonia, and carbon dioxide, so that the substance disappears.

Heat a little ammonium carbonate in an ignition-tube or dry test-tube, holding the tube in a paper holder so that it is sloping down slightly. Notice the steam and drops of water in the cooler part of the tube. Test for ammonia gas by smell and by holding a piece of damp red litmus paper at the mouth of the tube. The paper will be turned blue. Test also for carbon dioxide with lime-water as described at p. 43. After a while none of the white powder is left at the bottom of the tube.

**Action of Alkalis.** Warm a little ammonium carbonate in a test-tube with an inch of washing-soda solution or lime-water. Ammonia gas can again be detected by smell or by litmus.

**Action of Acids.** Add a little acid solution (vinegar, citric acid, etc.) to some ammonium carbonate in a test-tube. Note the effervescence, or bubbling. Test for carbon dioxide by lime-water.

**Precipitating Metal Carbonates.** Add a solution of ammonium carbonate to solutions of copper sulphate, ferrous sulphate, magnesium sulphate, zinc sulphate, and to lime-water. Precipitates of metal carbonates of various colours will be formed.

### *Ammonium Chloride*

*Common Name:* sal-ammoniac. *Chemical Formula:*  $\text{NH}_4\text{Cl}$ .

Ammonium chloride is a white powdery, crystalline substance

which is very soluble in water. The solution is neutral to litmus. This chemical is widely used in electric cells, such as the Leclanché cell and flashlight batteries. It can be obtained from a spent battery as now described.

**Obtaining Sal-ammoniac (and Manganese Dioxide) from a Dry-cell.** The various parts of a dry-cell, after removal of the paper wrapping, are illustrated in Fig. 61, p. 196. The layer of pitch which seals the cell is best removed by softening it by warming, after which it can be scraped away with a penknife. The black mixture below consists chiefly of two chemicals, white sal-ammoniac and black manganese dioxide.

Scrape out as much of the black mixture as you can into a beaker and stir it up with a test-tubeful of hot water. This will dissolve the sal-ammoniac but not the manganese dioxide. Filter the black liquid into an evaporating-dish. The filtrate is a colourless solution of ammonium chloride. Evaporate the solution to about one-third, and then leave the dish in a warm place to complete the evaporation.

White crystals of ammonium chloride will be obtained. The black residue of manganese dioxide (impure) in the filter-paper can be used for experiments described later (see p. 85).

**Action of Heat.** Sal-ammoniac is well known for its property of 'subliming' when heated—that is, it does not melt like most substances do. It changes straight from solid into a gas or vapour.

Put a saltspoonful of ammonium chloride into a dry test-tube or ignition-tube and warm it over a small flame. The solid will gradually disappear from the bottom of the tube and a white deposit called a 'sublimate' will be formed part-way up the tube. This is caused by the vapour condensing again in the cooler part of the tube. The sublimate, or deposit, will be driven still farther up the tube if it is heated.

**Action of Alkalis.** Warm a little sal-ammoniac in a test-tube with an inch of washing-soda solution or lime-water. Ammonia gas will be given off.

**Obtaining Hydrogen.** Make a mixture of two saltspoonfuls of ammonium chloride with an equal amount of iron filings. Put the mixture into a dry tube and heat it. Hydrogen gas will be given off as well as ammonia. If a lighted taper or spill is put to the mouth of the tube the hydrogen will explode with a sharp 'pop.'

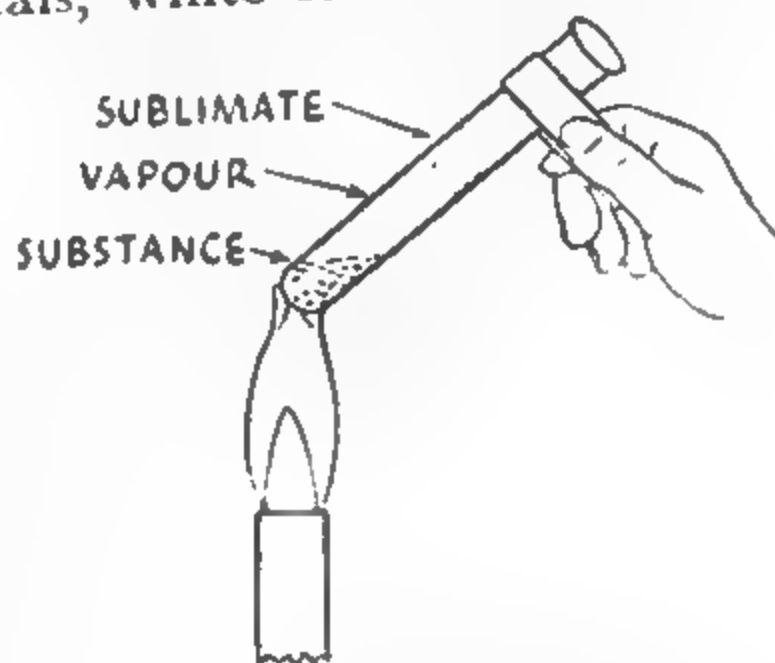


FIG. 22. EFFECT OF HEAT ON SAL-AMMONIAC

**White Sand from Yellow Sand.** Mix together equal amounts of clean, ordinary sand and sal-ammoniac. Put the mixture into a small metal screw-cap and heat it strongly, holding the cap in a pair of pliers or pincers. The sal-ammoniac will come off as white fumes and carry with it the impurities (chiefly iron compounds) which make the sand yellow. This action has been used commercially to purify sand for glass manufacture.

**Crystallizing Sal-ammoniac.** When sal-ammoniac is crystallized from solution it forms beautiful crystals of a feathery or fern-like pattern.

Make a strong solution of ammonium chloride by warming half an inch of the chemical with an inch of water in a test-tube. Use the solution to write your name on a small mirror or piece of clean glass with a small paint-brush. When the water has evaporated the writing will stand out boldly in crystals which resemble ice. You can see the fern-like pattern with the naked eye but the beauty of the crystals can only be observed properly by means of a magnifying glass. Ammonium chloride solution is sometimes used for writing advertisements on shop windows.

### *Ammonium Sulphate*

*Common Name :* sulphate of ammonia. *Chemical Formula :*  $(\text{NH}_4)_2\text{SO}_4$ .

This is a white crystalline substance which is very soluble in water. If the chemical is pure the solution is neutral to litmus. If your father is a keen gardener you will probably find that he has some ammonium sulphate in his stock of fertilizers. It is a valuable fertilizer for plants on account of the nitrogen which it contains.

Ammonium sulphate is a salt and has the property of combining with certain other salts. The products are known as 'double salts' and are interesting because of the beautiful shapes and colours of the crystals which they readily form. Ammonium sulphate combines with ferrous sulphate to give ferrous ammonium sulphate, with copper sulphate to give copper ammonium sulphate, and with aluminium sulphate to give ammonia alum.

**Preparing Crystals of Ferrous Ammonium Sulphate.** Put half an inch of ammonium sulphate crystals into a test-tube and add half an inch of water. Dissolve the crystals by shaking the tube. Into another test-tube put an inch of ferrous sulphate crystals and an inch of *cold* water. Dissolve these crystals also. Pour both solutions into an evaporating-dish and leave the dish overnight in the bottom of the airing-cupboard. Green crystals of ferrous ammonium sulphate,  $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ , will be deposited at the bottom of the dish.

Ferrous ammonium sulphate forms flat, square crystals (see

Plate 5). A large crystal of this substance can be grown as described in Chapter VII. The crystals, unlike those of ferrous sulphate, do not oxidize or turn yellow on exposure to air.

**Preparing Crystals of Copper Ammonium Sulphate.** This double salt is prepared in a similar manner to ferrous ammonium sulphate, copper sulphate being substituted for ferrous sulphate. Slightly more water is required to dissolve the copper sulphate. The crystals obtained have a beautiful light blue colour. Their shape is shown in Plate 5. Their chemical formula is  $\text{CuSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ .

**Preparing Crystals of Ammonia Alum.** For this preparation about five times as much aluminium sulphate is required as ammonium sulphate. Use about a quarter of an inch of ammonium sulphate crystals in a test-tube. Dissolve the two substances separately using a quantity of water about equal to that of the crystals. Mix the solutions in an evaporating-dish and leave the mixed solution to evaporate. The colourless crystals deposited will be diamond-shaped like those of potash alum (p. 54). Their chemical formula,  $(\text{NH}_4)_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ , is also similar to that of potash alum.

**Obtaining Ammonia Gas.** Warm half an inch of ammonium sulphate with about an inch of washing-soda solution or lime-water in a test-tube. Ammonia will be given off. The gas can be recognized by its smell and by the turning blue of red litmus paper.

### *Baking-soda*

(Bicarbonate of soda)

See Sodium Bicarbonate.

### *Bleaching Powder*

**Common Name:** chloride of lime. **Chemical Formula :**  $\text{CaOCl}_2$ .

This is a greyish-white powder, and, as its name indicates, it is used for bleaching materials—that is, turning them white. It is also used for disinfecting sinks and drains. When the powder is mixed with water part of it dissolves, and if the liquid is filtered the filtrate is found to have a powerful bleaching and disinfecting action.

**Effect of exposing to Air.** *Cautiously* sniff some bleaching powder. You will notice a choking smell. The smell is caused by chlorine gas which is generated from the powder by the action of carbon dioxide present in the air. Hold pieces of wet litmus paper, red and blue, over the powder. The paper will be bleached by the fumes of chlorine.

**Obtaining Chlorine Gas.** Put a saltspoonful of bleaching powder into a test-tube and add a few drops of any acid solution (vinegar, alum, citric acid, etc.). Chlorine gas will be given off readily. Test

the gas with wet litmus paper. Hold a piece of white paper behind the tube and note the green colour of the chlorine in the tube.

**Bleaching with Bleaching Powder.** Put one drop of ink into half a test-tubeful of water to make a blue solution. Add one salt-spoonful of bleaching powder. The blue colour of the liquid will vanish.

You can make an ink-eraser from bleaching powder as follows. Put a saltspoonful of the powder into an egg-cupful of cold water and leave it for quarter of an hour. Then pour off the liquid, and with a small brush paint it over the writing which you wish to erase. When the writing has disappeared wash the brush and paint some citric or tartaric acid solution over the place. This will prevent damage to the paper by excess of the bleaching liquid.

Put a few strips of cloth of different colours into a jam-jar half full of water. Add a couple of teaspoonfuls of bleaching powder and stir. Leave the cloth in the liquid for a few hours and find which of the samples have been bleached.

**Oxygen from Bleaching Powder.** There are several ways of producing oxygen from this chemical. Some of them make use of 'catalysts.' These are substances which help chemical actions to take place but are not changed themselves when the actions are over. In each case test the oxygen given off by a glowing wood spill, which should relight.

(i) Warm half an inch of bleaching powder in a dry tube over a small flame.

(ii) Put half an inch of bleaching powder into a test-tube and add about an inch of cobalt chloride solution. The liquid will turn black. When the tube is warmed oxygen will be given off in abundance.

(iii) Take two test-tubes and add to each half an inch of bleaching powder and about an inch of water. Warm each tube gently for half a minute. No oxygen will be given off. Now add to the first tube a few drops of copper sulphate solution and to the second tube a few drops of ferrous sulphate solution. There will be a little effervescence in each case, but not enough oxygen will be given off to relight the glowing spill. Finally pour the contents of one tube into the other tube. Oxygen will now be given off in large quantities, and the glowing spill will easily relight. Evidently in this case two catalysts are better than one.

### *Boracic Acid*

*Chemical Name:* boric acid. *Chemical Formula:*  $\text{H}_3\text{BO}_3$ .

Boracic acid may be in the form of a white powder or white silky crystals. The substance is only slightly soluble in cold water but is fairly soluble in hot water. The solution is a very weak acid and



scarcely affects blue litmus paper. Boracic acid is commonly used as an antiseptic in boracic powder and ointment.

**A Flame Test for Boracic Acid.** Put a teaspoonful of methylated spirit into an evaporating-dish or clean tin-lid in a saucer. Add a saltspoonful of boracic acid and then set fire to the methylated spirit. A bright green flame will result. The test works better if one or two drops of glycerine are added and the mixture stirred while it is burning.

**A Different Way of doing the Flame Test.** Boracic acid is volatile in steam—that is, if a solution of the substance is boiled boracic acid vapour is given off along with the steam.

Put a saltspoonful of boracic acid into a test-tube with about an inch of water. Hold the tube in a paper holder and heat it over a small flame until the solution begins to boil. Then continue the boiling with a candle flame and hold the flame of the Bunsen burner in the steam which is coming from the tube. The Bunsen flame will immediately turn green.

**Effect on Turmeric Paper.** When a turmeric paper is moistened with boracic acid solution the paper turns a reddish-brown colour. If then the paper is moistened with an alkali such as ammonia or washing-soda solution the colour changes to a dark green.

**Making Boracic Acid Crystals from Borax.** For this you require strong solutions of borax and of sodium bisulphate.

Put about an inch of each of the above chemicals into separate test-tubes and dissolve them by warming with about an inch of water. Cool the tubes by holding them under the tap. When the tubes are cold pour the solution from one tube into the other tube and hold the mixture up to the light. A beautiful shower of sparkling crystals will be seen falling through the liquid like a miniature snowstorm.

When the crystals have settled they can be filtered off and tested to show that they consist of boracic acid. Wet the end of a match or wood spill, dip it into the crystals, and then introduce it into a flame. The flame will turn green.

### *Calcium Carbonate*

*Common Forms:* chalk, limestone, marble, coral, egg-shells, sea-shells. *Chemical Formula:*  $\text{CaCO}_3$ .

Calcium carbonate is found in a number of different forms, as given above. These look different because they have been made in different ways. Thus chalk was first formed at the bottom of the sea from the shells of tiny sea-creatures; marble was formed inside the earth where heat and pressure made it very hard; coral is the bony skeleton of an organism living in warm tropical seas. In spite of



their different appearance, all these substances consist of the same chemical and their chemical actions are therefore similar. Black-board 'chalk' is not real chalk; it is made of calcium sulphate (see p. 65).

Calcium carbonate is insoluble in pure water, although a little can dissolve if the water already contains dissolved carbon dioxide. This is important because it has the effect of making the water 'hard' (p. 128).

**Action of Heat on Calcium Carbonate.** Very strong heat is required to decompose any of the forms of this chemical. Heat about

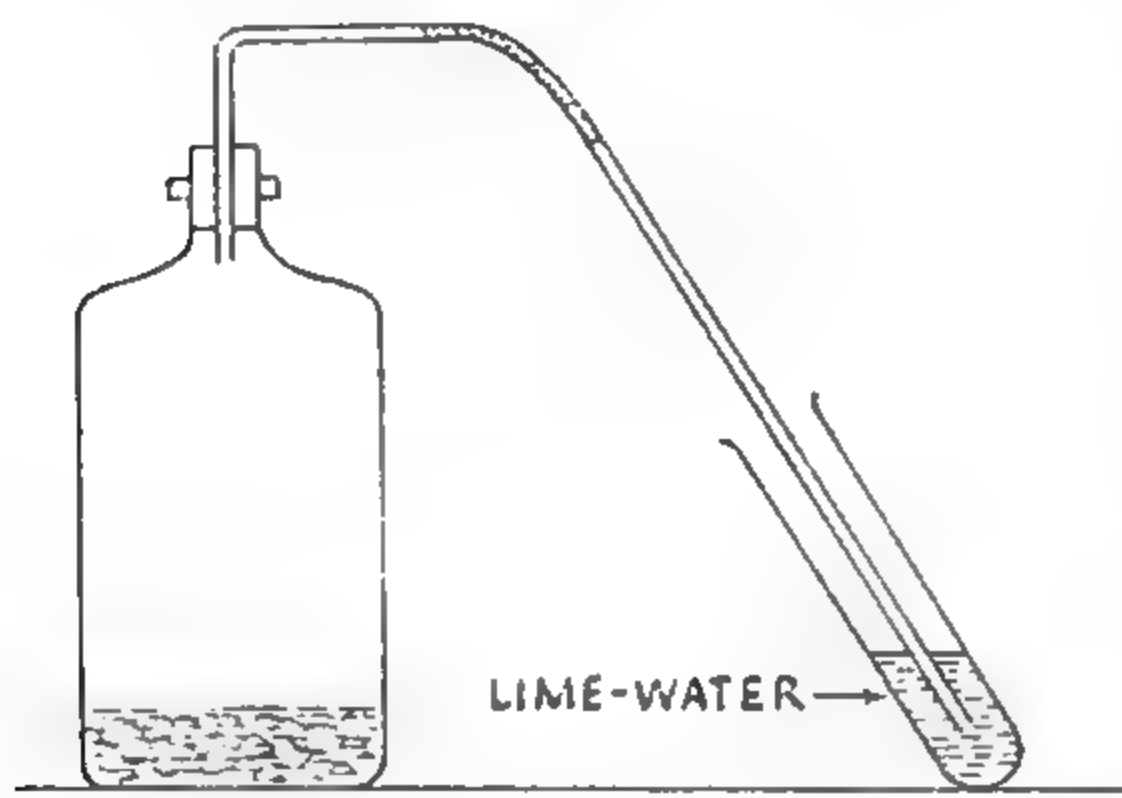


FIG. 23. APPARATUS TO INVESTIGATE THE ACTION OF ACIDS ON CHALK, EGG-SHELLS, ETC.

an inch of chalk at first gently and then strongly in a hard-glass tube, using a paper holder for the tube. If, when the end of the tube is red-hot, you apply the lime-water test (p. 43) you will probably get sufficient carbon dioxide to turn the lime-water milky.

**Action of Acids.** The easiest way to obtain carbon dioxide from calcium carbonate is to treat it with an acid, but some acid solutions

(sulphuric acid, sodium bisulphate, alum) are not suitable to use because the action quickly stops. Vinegar, citric acid, or tartaric acid can be used.

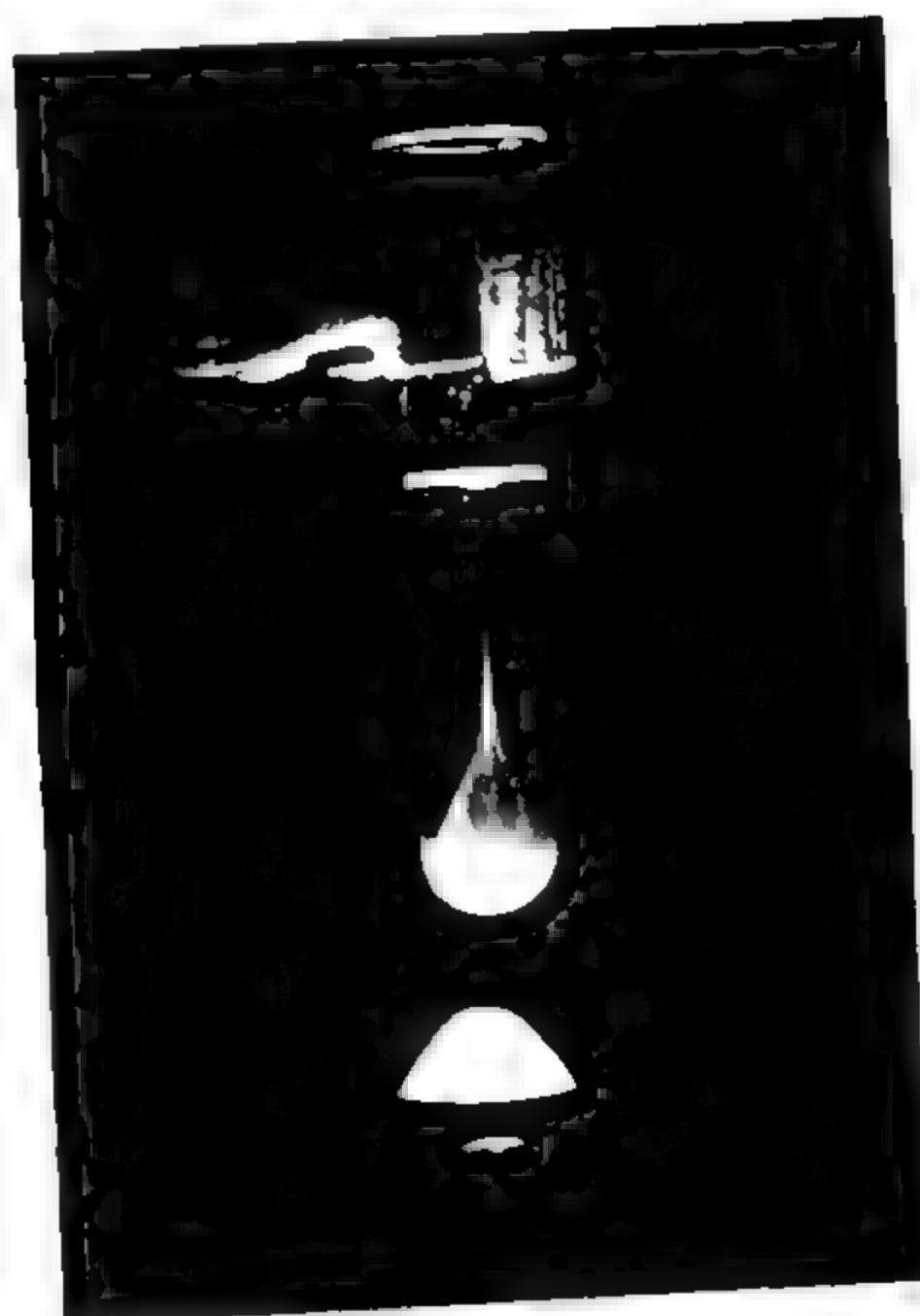
A good apparatus for investigating the action with different forms of calcium carbonate is shown in Fig. 23.

Put a layer of chalk or pieces of marble, coral, egg-shells, or sea-shells in a large medicine bottle. Fit the latter with a cork and a right-angled piece of glass tubing which is attached by rubber tubing to a tube dipping into some lime-water. When you have fitted up the apparatus pour enough of the acid solution into the bottle to cover the solid material. Replace the cork. The length of time taken for the lime-water to turn milky depends on which form of calcium carbonate you have used and on the strength of the acid.

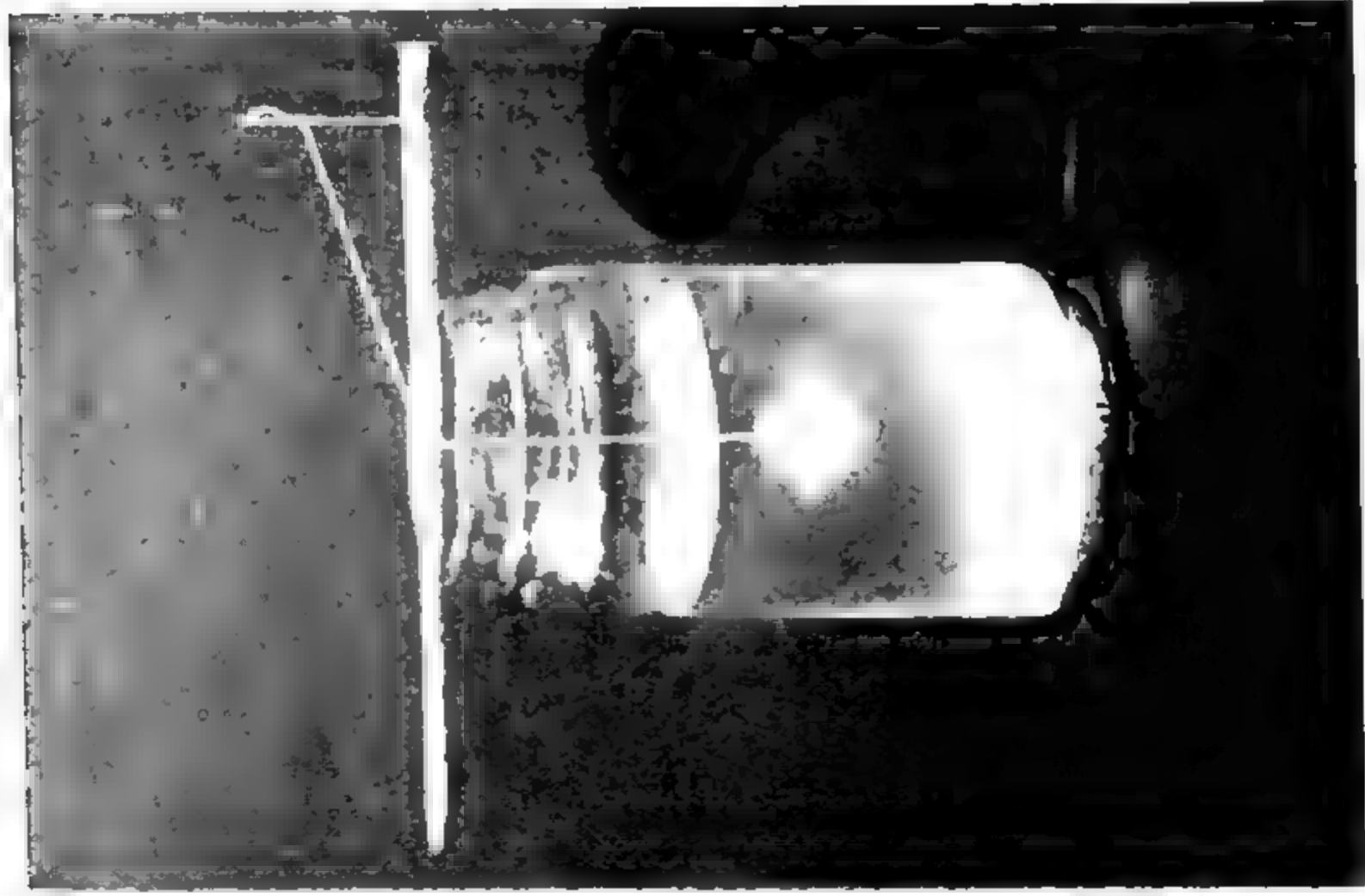
When the action is over pour off the liquid remaining in the bottle into a beaker and add to it a strong solution of washing-soda. A white precipitate of chalk will be formed.



USING A HOME-MADE BLOWPIPE  
See p. 12.



TESTING THE FLUORESCENCE  
OF CHEMICALS  
See p. 138.

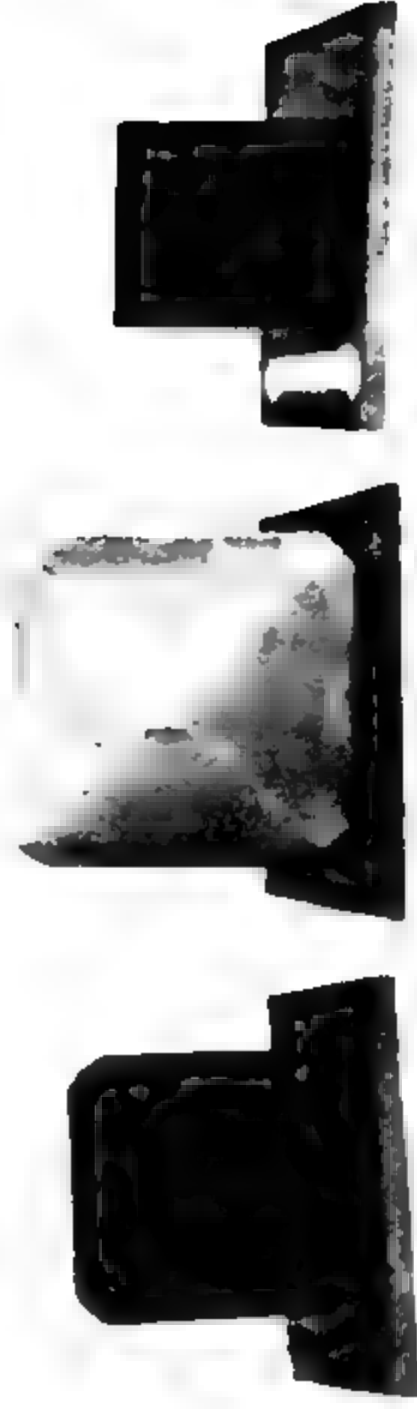


THE COTTON SEED IS GROWING A CRYSTAL

2000 X



VERY LARGE CRYSTALS OF IRON SULFIDE



IRON-GROWN CRYSTALS OF IRON SULFIDE, POLYMER SULFIDE AND CHROMIUM SULFIDE  
WITH A LUMEN FOR COMPARISON

*Calcium Hydroxide*

See Lime.

*Calcium Sulphate*

*Common Forms:* blackboard 'chalk,'  $\text{CaSO}_4$ , and plaster of Paris ( $2\text{CaSO}_4 \cdot \text{H}_2\text{O}$ ).

Plaster of Paris can be bought at a decorator's shop. It is a white or slightly pink powder used in decorating, for mending broken limbs, and for making plaster casts and ornaments. It has the peculiar property when mixed with water of setting, or going hard, in a few minutes. It is a very useful substance to have in your stock of materials, as it can be used for making various items of home-made apparatus (see, for example, pp. 115 and 227). It is therefore worth while buying a pound or two. It should be stored in a dry place; otherwise it may have absorbed moisture and become hard when you wish to use it.

Both plaster of Paris and blackboard chalk are manufactured by heating a naturally-occurring form of calcium sulphate called gypsum,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ , different temperatures being used in the two cases. Blackboard chalk is anhydrous calcium sulphate<sup>1</sup>. Coloured chalks are made by mixing various dyes with the white material.

**Showing that Blackboard Chalk is not Real Chalk.** Add some vinegar or citric acid solution to a little blackboard chalk in a test-tube. There will be no effervescence, showing that no carbon dioxide is produced (a few bubbles due to air in the pores of the chalk may be seen). A lime-water test will give a negative result.

**Showing the Slight Solubility of Calcium Sulphate.** Shake a little plaster of Paris or powdered blackboard chalk with about two-thirds of a test-tubeful of water for a few minutes. Filter the milky liquid into another test-tube through two filter-papers folded together (as the powder is very fine it tends to pass through a single filter-paper). The filtrate should be quite clear.

Pour half the liquid into an evaporating-dish and evaporate to dryness on a gauze and tripod over a small flame. A very small white residue will be left in the dish, showing that calcium sulphate dissolves slightly in water.

Test the other half of the solution by adding to it a few drops of soap solution made by dissolving a fragment of soap in half a test-tubeful of water. When the mixture is shaken a scum will collect on the water. The scum is formed by chemical action between the soap and the calcium sulphate in solution. Calcium sulphate is one of the chemicals which make water 'hard' and waste soap in washing (p. 128).

<sup>1</sup> A substance is described as 'anhydrous' when it has lost its water of crystallization.

**Making a Plaster Cast of a Medal.** When you are using plaster of Paris to make casts you will find it more convenient to use cold tea rather than water to harden the plaster. With water setting occurs in a few minutes; with cold tea (the liquid left in the tea-pot after a meal will do) setting does not take place for about half an hour or even longer. This gives you more time in which to work.

Put two tablespoonfuls of plaster of Paris into a small basin or saucer. Add cold tea to the powder, a few drops at a time from a test-tube, and stir until the mixture is like a thick dough or paste. Transfer the mixture to a tin-lid and press it flat with the back of a spoon. Press a medal into the surface until the top of the medal is

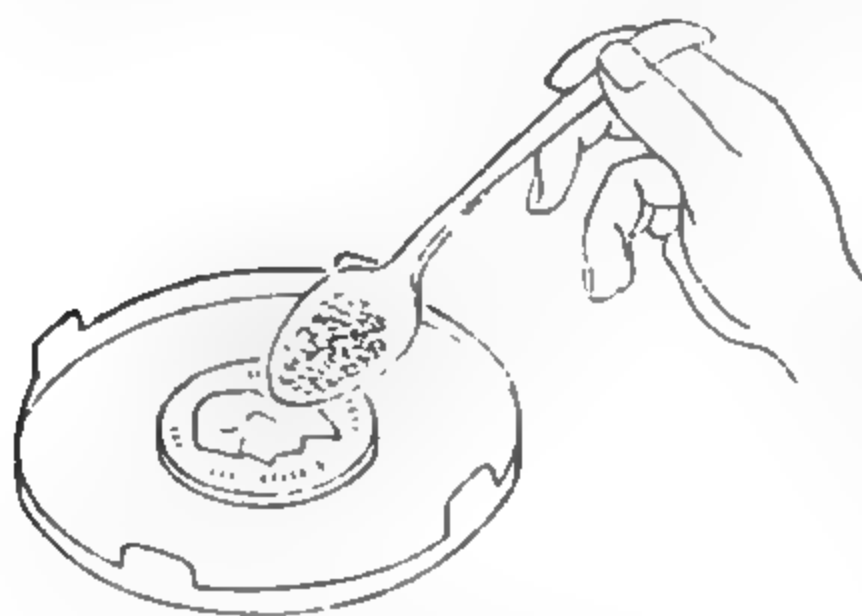


FIG. 24. POURING MELTED LEAD INTO A PLASTER MOULD

level with the plaster. Leave it for an hour. At the end of that time the plaster should have set. Remove the medal by lifting it on one side with the point of a sharp knife. You will find a faithful copy of the lower side of the medal in the plaster. The details of the cast will be shown up clearly if you rub a little powdered carbon or graphite from a lead pencil over the inside.

The ability of plaster of Paris to reproduce fine details in the shape of an object is due to the expansion which it undergoes in setting. This results in the paste being pushed into all the corners and tiny crevices of the object.

When wet plaster of Paris is left too long in a basin or saucer it sets and is very difficult to remove. This difficulty can be overcome by soaking the hardened plaster for a while in vinegar. It can then be scraped out easily with a knife.

**Making a Copy of a Medal in Lead.** The plaster cast which you have made can be used as a mould for making a lead copy of the medal. Some lead can be easily obtained from an old tooth-paste tube or lead solder can be used.

*It is important to dry the mould thoroughly before using it.* This can be done by leaving it for 24 hours in a warm airing-cupboard. If this precaution is not taken and molten lead is poured into the damp mould, the metal will 'spit' and perhaps burn you badly.

Clean the lead, cut it into small pieces, and put the pieces into an old tablespoon. Hold the spoon in a duster and melt the lead over a Bunsen flame. Pour the molten metal quickly into the mould, and while it is solidifying press it down with the back of the spoon. When

the metal is cold, lift it by pushing the point of a penknife under the rim. You will now have a copy of one side of the medal.

### Carbon

*Common Forms:* charcoal, soot, graphite, or blacklead, diamond, coke (a very impure form). *Chemical Symbol:* C.

Carbon is a non-metallic element and is interesting for the wide variety of forms in which it occurs. There are several kinds of charcoal, the best known being wood charcoal and bone, or animal, charcoal. Wood charcoal is a porous black solid used for making gunpowder and for absorbing gases. It also has the power of absorbing colouring matter from liquids, although bone charcoal is even better for this purpose. Bone charcoal is used in the manufacture of white sugar. 'Lump' wood charcoal is the most suitable kind to buy for the following experiments.

**Making Charcoal from Wood.** Put a few small pieces of wood in a crucible or tin (without a lid) and cover the pieces with a layer of sand or salt up to an inch thick. Heat strongly over a Bunsen flame for five minutes. The wood will be converted into charcoal. The purpose of the sand or salt is to exclude air.

Another method of preparing wood charcoal is described at p. 147.

**Is Charcoal heavier than Water?** Put a lump of charcoal into some water. It will float. Now wrap some thick copper wire round the lump or tie a stone to it to make it sink. Put the weighted lump into a beaker or small pan, cover it with water, and boil the water for ten minutes. Remove the charcoal, cool it under the tap, and take away the weight attached to it. The charcoal will now sink in water.

Charcoal is really heavier than water, but it usually floats because of the air trapped in its pores. When the charcoal is boiled in the water the air is removed. A small piece of coke can be used in place of charcoal in this experiment.

**Removing Colour with Charcoal.** Make some coloured water by adding to an inch of water in a beaker a drop of cochineal solution or gravy browning, or a little black treacle. The colour must not be too strong. Add two or three teaspoonfuls of powdered charcoal made by crushing a lump. Stir the liquid well and boil it for ten minutes on a gauze and tripod. Allow the beaker to cool and then filter a little of the contents. The filtrate will be quite colourless.

**Absorbing Gases with Charcoal.** Ammonia and chlorine are the best gases to use for this experiment.

Put about a dozen small pieces of charcoal on a tin-lid, hold the lid in a pair of pliers or pincers, and warm the charcoal by holding



the lid an inch or two above a small flame. This will drive off any gases contained in the charcoal. Allow the lid to cool.

Add one or two drops of strong ammonia solution to a test-tube and empty the liquid out again. The tube will still smell strongly of ammonia gas. Put half a dozen pieces of the warmed charcoal into the tube, place your thumb over the end, and shake the tube for about a minute. The smell of the ammonia will have disappeared.

To prove that the ammonia gas has been absorbed by the charcoal empty out the pieces of charcoal on to a piece of filter-paper or blotting-paper and dry them if necessary. Then put them into a dry test-tube and place a piece of damp red litmus paper in the mouth of the tube. Warm the tube. The litmus paper will turn blue, and it will be possible to smell the ammonia at the end of the tube.

The experiment can be repeated with chlorine gas. Some of the latter can be made by putting a saltspoonful of bleaching powder or a drop of bleaching fluid into a test-tube and adding a saltspoonful of citric acid and a drop of water. In this case the chlorine given off from the charcoal in the final stage of the experiment will bleach the damp litmus paper.

**Obtaining Metals from Metal Oxides with Carbon.** Carbon will take the oxygen from a number of metal oxides and leave the metals. Substances which do this are called 'reducing agents.' You can illustrate this property of carbon by using charcoal to make copper from copper oxide or lead from either litharge or red lead, both of which are oxides of lead.

On a piece of paper mix a saltspoonful of copper oxide, litharge, or red lead with about five saltspoonfuls of powdered charcoal. Put the mixture into a small metal screw-cap from a bottle (remove the cork or paper lining from the cap first). Cover the mixture with more charcoal to exclude air. Hold the cap in a pair of pliers or pincers and heat it strongly for five minutes over a Bunsen flame. Then allow the cap to cool on an asbestos pad or wire gauze. When the cap is cool wash it out by letting water drip into it from the tap. You will find some small red particles of copper or beads of lead left at the bottom of the cap. If the lead is scraped with a penknife the shiny surface of the metal will show up clearly.

Another method of using charcoal as a reducing agent is described at p. 123.

### *Caustic Soda*

*See Sodium Hydroxide.*

### *Chloride of Lime*

*See Bleaching Powder.*

### *Chrome Alum*

*Chemical Name:* potassium chromium sulphate. *Chemical Formula:*  
 $K_2SO_4 \cdot Cr_2(SO_4)_3 \cdot 24H_2O$ .

Chrome alum is similar in many ways to the common potash alum (p. 54). It is made by mixing together solutions of potassium sulphate and chromium sulphate and crystallizing out. Deep violet-black crystals are formed. The crystals are readily soluble in water, giving an acid solution which turns blue litmus red. Chrome alum is used in dyeing and in tanning leather.

**Crystallizing Chrome Alum.** Beautiful violet crystals of this substance can be grown from a saturated solution on a piece of weighted cotton, as described for potash alum (p. 55). The crystals obtained are diamond-shaped like those of potash alum. The growing of a large crystal of chrome alum is described in Chapter VII (see also Plate 4).

**Change of Colour of Chrome Alum.** Boil a dilute solution of the chemical in a test-tube. The colour, which is at first violet, will turn green. If the solution is allowed to cool and stand for a short time the violet colour will return.

**Action of Washing-soda.** Add a little washing-soda solution to a solution of chrome alum in a test-tube. A light green gelatinous precipitate will be formed. Now add a few drops of hydrogen peroxide to the tube and boil the contents. A yellow solution due to the formation of sodium chromate will result. If a piece of filter-paper wetted with the yellow solution is put into a jar containing sulphur dioxide gas (p. 175) the paper will turn green.

**Action of Ammonia.** Add dilute ammonia to a solution of chrome alum. A light green precipitate of chromium hydroxide will be thrown down. This precipitate, like aluminium hydroxide, has a great attraction for dyes and is used as a mordant to make dyes stick to a cloth (p. 139).

### *Cobalt Chloride*

*Chemical Formula:*  $CoCl_2 \cdot 6H_2O$ .

This is rather an expensive chemical, but half an ounce will be sufficient to carry out the experiments described. Cobalt chloride consists of red crystals which are very 'deliquescent'—that is, they absorb moisture from the air and form a solution. The crystals should therefore be kept in a tightly stoppered bottle. The solution is acidic.

**Action of Heat.** Allow two or three drops of cobalt chloride solution to fall on a piece of filter-paper or white blotting-paper. Warm the paper in front of the fire or by holding it above a small flame. As the moisture evaporates the paper will turn a brilliant blue colour.

The change of colour is caused by the driving off of the water of crystallization from the substance. The remaining anhydrous cobalt chloride is blue. The red colour is restored after a short time owing to moisture being absorbed from the air.

**A Chemical Weather Indicator.** Make a fairly strong solution of cobalt chloride by dissolving a saltspoonful of the crystals in half an inch of water in a test-tube. Paint a strip of plain white paper with the solution and allow it to dry. Pin the paper to a board and place the board outside in fine weather where sunlight will fall directly on the paper. If the weather is warm and sunny the paper will turn blue. It will become red again when rain is expected.

**Action of Ammonia.** Add a little dilute ammonia to some cobalt chloride solution in a test-tube. A greenish-blue precipitate will be formed. If more ammonia is added the precipitate will dissolve and produce a green liquid.

**Action of Lime-water.** Add some lime-water to cobalt chloride solution. A light blue precipitate will be formed which will turn bright green if the test-tube is heated.

**Action of Sodium Carbonate.** Add a little washing-soda solution to cobalt chloride solution. A rose-pink precipitate will be thrown down. Heating the test-tube will cause the precipitate to turn violet.

Cobalt chloride gives a blue borax bead (p. 120). It is also used for testing chemicals for the presence of aluminium (p. 57), magnesium (p. 85), and zinc (p. 101).

### *Copper*

*Chemical Symbol:* Cu.

Copper is a metallic element and is largely used in everyday life for conducting a current of electricity. It is also used in making alloys, such as brass (copper and zinc), bronze (copper and tin), and 'copper' coins.

**Oxidizing a Copper Coin.**<sup>1</sup> Hold a copper coin by the edge in a pair of pliers and heat it at the tip of a hot flame. The surface of the coin will turn black, because the copper in the coin combines with oxygen in the air to form black copper oxide, or cupric oxide,  $\text{CuO}$ . After two or three minutes' heating allow the coin to cool and then scratch it with the point of a penknife. Below the black layer will be found a red layer which consists of another oxide of copper called cuprous oxide,  $\text{Cu}_2\text{O}$ . Underneath this again will be found unchanged copper.

<sup>1</sup> It is illegal to use the King's coinage for any purpose except that of currency. If you want to be on the right side of the law you will have to use a foreign coin in this experiment.

Place the blackened coin in a beaker and warm it with a little dilute sulphuric acid, sodium bisulphate solution, or dilute nitric acid. The surface of the coin will be cleaned, and a blue solution of either copper sulphate or copper nitrate will be formed.

The surfaces of copper coins in everyday use become black with age because copper combines with oxygen and hydrogen sulphide gases present in the atmosphere to form copper oxide and copper sulphide, which are both black. The black coating can be removed and the discoloured coin made bright and shiny by warming with dilute nitric acid. Dilute sulphuric acid will dissolve the copper oxide but not the copper sulphide.

**Obtaining Copper from Brass.** This experiment can also be carried out with a small copper coin.

Warm a small piece of brass or a few bits of brass wire in a test-tube half full of dilute nitric acid, using only a small flame. Soon effervescence will begin and a brown gas, nitrogen peroxide, will be seen in the tube. At the same time a greenish-blue solution of copper nitrate will be formed.

Allow the action to proceed for about five minutes and then pour the solution into an egg-cup. Put a clean penknife blade into the solution. A deposit of pure copper will be formed on the blade.

**A Flame Test with Copper.** Dip the end of a copper wire into some iodine solution (tincture of iodine) and introduce the wire into the edge of a flame. A bright green colour will be imparted to the flame. This has a beautiful appearance in the dark.

### *Copper Oxide*

*Chemical Name:* cupric oxide. *Chemical Formula:*  $\text{CuO}$ .

Cupric oxide, the more common of the two oxides of copper, is a black powder. It is insoluble in water, but dissolves readily when warmed with an acid. Methods of reducing copper oxide to copper are described at pp. 68 and 123. Another method of carrying out this experiment is as now described.

**Obtaining Copper from Copper Oxide.** Mix together a saltspoonful of copper oxide, one of sodium bicarbonate (or powdered washing-soda), and two of sugar. Put a saltspoonful of the mixture into a small metal screw-cap or on to a tin-lid. Heat the mixture over a medium Bunsen flame. The mixture will swell up and form a copper-coloured mass.

To obtain the copper from the mass allow the screw-cap or lid to cool and powder the copper-coloured residue. Put the powder into a test-tube and warm it for a few minutes with a little dilute sulphuric acid or sodium bisulphate solution. Pour away the contents of the tube except for the small amount of solid left at the bottom of the

tube. This solid will be found to consist of small particles of metallic copper.

**Making Copper Sulphate Crystals from Copper Oxide.** When black copper oxide is warmed with dilute sulphuric acid it is converted into a blue solution of copper sulphate.

Half fill a test-tube with dilute sulphuric acid. Holding the tube in a paper holder, warm it over a small flame until the liquid nearly begins to boil. Then add a pinch of copper oxide from a saltspoon to the tube. The black powder will dissolve. Warm the tube again and add a further pinch of copper oxide. This also will dissolve. Continue the adding of small amounts of copper oxide and warming until a black sediment of copper oxide stays at the bottom of the tube, even after warming for a minute or two.

Filter the blue solution into an evaporating-dish and leave it to evaporate in the bottom of the airing-cupboard. Blue crystals of copper sulphate will be deposited in a few hours on the bottom of the dish.

### *Copper Sulphate*

*Common Names:* blue vitriol, blue stone. *Chemical Formula:*  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ .

This well-known chemical consists of blue crystals, which dissolve easily in water to form an acid solution. The crystals contain water of crystallization, which is given off as steam when the crystals are heated. The white product (anhydrous copper sulphate) is used to test chemically for water (p. 46). Copper sulphate is poisonous and should not be put into vessels used in the household.

**A Yellow Invisible Ink.** To a test-tube nearly full of water add a saltspoonful of powdered copper sulphate and a saltspoonful of ammonium chloride. Dissolve the substances by putting your thumb over the end of the tube and turning the tube upside down a few times. Write on a piece of paper with the faintly blue solution, using a small paint-brush for the purpose. When the writing has dried it will be invisible. By warming the paper in front of the fire or over a small flame the writing can be made to appear in yellow letters.

**The Insolubility of Copper Sulphate in Methylated Spirit.** Make a strong solution of copper sulphate by warming half an inch of the powdered substance with about an inch and a half of water in a test-tube. When the powder has dissolved cool the tube under the tap. Pour into the tube a few drops of methylated spirit. A shower of very small crystals of copper sulphate will be thrown down in the tube because copper sulphate is insoluble in methylated spirit.

**Obtaining Copper from Copper Sulphate.** Shake up a salt-spoonful of iron filings with an inch of blue vitriol solution in a



test-tube for a few minutes. The colour of the solution will fade, and, if the shaking is continued long enough, will disappear. Filter the contents of the tube. A reddish-brown powder will be left in the filter-paper. The chemical action is as follows:

Copper sulphate + iron  $\rightarrow$  copper + iron (ferrous) sulphate.

The reddish-brown powder is not pure copper, as excess of iron filings have been used in the experiment; it is a mixture of copper and excess iron filings coated with copper.

Instead of iron filings zinc (p. 100) or lead can be used. Obtain a strip of lead from an old tooth-paste tube. After cleaning the lead rub it with sandpaper and then immerse it in a little hot copper sulphate solution. The heat is necessary because the action is slow in the cold. A film of copper will be deposited on the lead.

**Making Green Copper Carbonate and Black Copper Oxide.** To an inch of copper sulphate solution in a test-tube add an equal amount of washing-soda solution. A bluish-green precipitate of copper carbonate will be formed. The action, a double decomposition, can be represented as follows:

Copper sulphate + sodium carbonate  $\rightarrow$  copper carbonate + sodium sulphate.

Filter the precipitate, and with a spill transfer a little to a metal lid. Hold the lid in a pair of pliers and warm it gently over a small flame. The green colour will change to black, owing to the formation of black copper oxide (cupric oxide).

**Using Golden Syrup to make Red Copper Oxide.** Add a little sodium hydroxide (caustic soda) solution to an inch of blue vitriol solution. A blue jelly-like precipitate of copper hydroxide will be formed. Stir a little syrup on the end of a spoon into a little warm water until the syrup has dissolved. Add about an inch of this solution to the copper hydroxide in the test-tube. Warm the tube gently. Soon a yellow precipitate will be formed in the tube. This is cuprous oxide,  $\text{Cu}_2\text{O}$ , appearing in a yellow form. Gradually the colour will change to orange. At this stage filter off the precipitate. When the cuprous oxide is left for a time in the filter-paper it will turn red, its usual colour.

Instead of golden syrup in this experiment you can use a solution of black treacle, or the sweet sold as 'barley-sugar.' These materials contain glucose, a form of sugar necessary for the experiment. In Chemistry this chemical action is often used as a test for glucose. You can try the test on an apple. Warm a few small pieces of the apple with water, and, after filtering the liquid, use it in the same way as described for the syrup solution.



**The Action of Ammonia.** Put half an inch of blue vitriol solution into a test-tube and add dilute ammonia solution to the tube drop by drop. After adding each drop shake the tube. At first a light blue precipitate will be formed, but as more ammonia is added the precipitate will dissolve giving a deep royal blue solution. The colour is caused by the formation of a compound called cuprammonium sulphate.

To obtain the compound in solid form add a little methylated spirit to the tube. A violet-blue precipitate will be formed. If the precipitate is filtered it gives an excellent flame test for copper when introduced into a flame on the end of a wet spill or match.

The crystallization of copper sulphate is described at p. 38, and the growing of a large crystal of this substance at p. 163. A photograph of a large crystal is shown in Plate 5.

### *Epsom Salts*

*See Magnesium Sulphate.*

### *Ferric Chloride*

*Chemical Formula:*  $\text{FeCl}_3$ .

A solution of this chemical is usually kept in stock at the chemist's shop. Like alum, it is used for stopping bleeding from small cuts. If you take a small bottle to the shop you can get it filled with the brown solution for a copper or two. The solution can be used for carrying out most of the experiments described under Iron Alum.

### *Ferrous Sulphate*

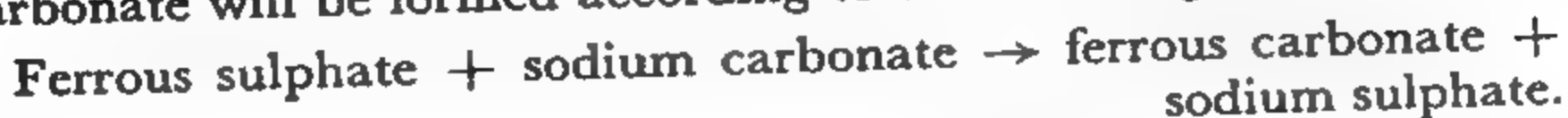
*Common Names:* green vitriol, iron sulphate. *Chemical Formula:*  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ .

Ferrous sulphate consists of green crystals, which dissolve in water to form a neutral solution. If the crystals are exposed to air they soon begin to turn brown. This is because the oxygen of the air converts ferrous sulphate into a brown sulphate of iron called ferric sulphate. To keep the crystals, therefore, they should be stored in a bottle with a tightly fitting stopper. The same change from green ferrous sulphate to brown ferric sulphate also occurs when a solution of the crystals is heated. For doing experiments you should make a solution by shaking the powdered crystals with *cold* water. Green vitriol is used in industry to make ink.

**An Invisible Ink.** Using a wood spill, write on a sheet of plain paper with green vitriol solution. Allow the paper to dry and then warm it by holding it in front of a fire or over a flame. The writing will appear yellow or brown.

**Action of Sodium Carbonate.** Add a little washing-soda solution to some ferrous sulphate solution. A green precipitate of ferrous

carbonate will be formed according to the following action:



**Action of Ammonia.** Add a few drops of dilute ammonia solution to an inch of ferrous sulphate solution in a test-tube and shake the tube. A dirty-green precipitate of ferrous hydroxide will be thrown down. The part of the precipitate left on the side of the tube will quickly turn brown, because oxygen from the air turns it into ferric hydroxide.

**Oxidizing Ferrous Sulphate to Ferric Sulphate.** This change can be brought about by heating ferrous sulphate solution with a substance rich in oxygen. Such a substance is hydrogen peroxide.

Boil an inch of ferrous sulphate solution in a test-tube with a few drops of hydrogen peroxide. The green colour will change to yellow or brown. Cool the tube under the tap and test the liquid (now ferric sulphate solution) by adding a little dilute ammonia solution. A brown precipitate of ferric hydroxide will be formed.

**Making Sulphuric Acid from Green Vitriol.** Sulphuric acid was at one time manufactured by heating green vitriol crystals. It was therefore called 'oil of vitriol,' a name which is still used for it to-day. The preparation of sulphuric acid by this method can be carried out with a hard-glass or Pyrex test-tube. The strong heat required will melt an ordinary test-tube.

Put an inch of powdered ferrous sulphate crystals into the hard-glass tube. Fit the latter with a cork through which passes a right-angled piece of glass tubing. The other end of the tubing should dip into a test-tube. It is desirable to clamp the hard-glass tube loosely in a stand. The home-made stand described at p. 115 is suitable for the purpose. If no stand is available, however, it is a good idea to get a friend to hold the tube in a paper holder while you attend to the heating. In any case, the tube must be kept sloping downward throughout the experiment. If this is not done moisture will condense in the cooler part of the tube, run back on to the hot glass, and crack the tube.

Heat gently at first, moving the flame about, and then more strongly. Water of crystallization will be given off at first and the substance will change to white anhydrous ferrous sulphate. With

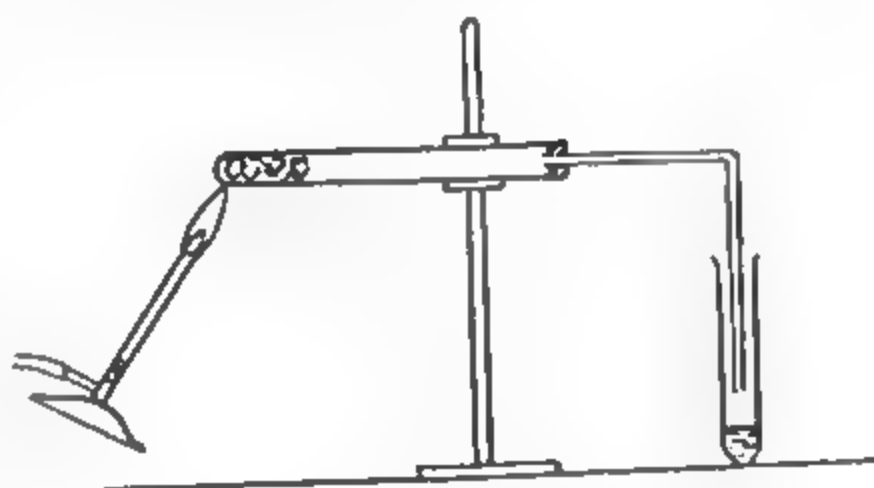


FIG. 25. APPARATUS USED FOR MAKING SULPHURIC ACID

stronger heat this will begin to decompose. A thick white vapour will appear, and will condense in the test-tube as a colourless liquid. When no more vapour is produced, allow the apparatus to cool.

The liquid collected in the test-tube is a weak solution of sulphuric acid. It can be tested by means of blue litmus paper and a crystal of washing-soda (carbon dioxide gas will be given off). The red substance left in the hard-glass tube is red iron oxide. It is also called jeweller's rouge, because jewellers use it for polishing gold and silver.

**Home-made Ink.** Black ink is made from ferrous sulphate and oak-galls, the round nut-like growths found on the branches of oak-trees, from which they can be collected in autumn. Crush or cut up one or two galls and boil the pieces with a little water in a beaker or small pan. The water will extract a chemical called tannic acid from the oak-galls. Strain off or filter the solution of tannic acid.

Make a fairly strong solution of ferrous sulphate in cold water and mix it with an equal amount of the cold oak-gall solution. This forms ferrous tannate in the liquid. Write on paper with the liquid. The writing will show little colour, but when left for a day or two will turn quite black. This is because the ferrous tannate on exposure to air turns into ferric tannate, which is black.

Ordinary blue-black ink contains a blue dye in addition to the ferrous tannate. The dye acts as temporary colouring matter until the black colour of the ferric tannate develops. You can make blue-black ink by adding to the ink prepared as above a solution of logwood or methylene blue, two common dyes. If methylene blue is used, however, the ink should be stored in a dark cupboard, because light will make the colour fade.

*Note.* You can use ferrous sulphate to do most of the experiments described under Iron Alum, providing that the ferrous sulphate solution is first oxidized to ferric sulphate by boiling it with a few drops of hydrogen peroxide as described previously.

### *Glauber's Salt*

*See Sodium Sulphate.*

### *Green Vitriol*

*See Ferrous Sulphate.*

### *Hydrogen Peroxide*

*Common Name:* peroxide (of hydrogen). *Chemical Formula:*  $\text{H}_2\text{O}_2$ .

Hydrogen peroxide is sold as a colourless solution for disinfecting and for bleaching hair, silk, and wool. Its chief property is that it

readily parts with one of its two oxygen atoms and turns into water ( $\text{H}_2\text{O}$ ). It is this oxygen which is responsible for the disinfecting and bleaching actions.

The strengths of the solutions usually sold are marked as '10 volume,' '20 volume,' etc. These figures refer to the volume of oxygen given by 1 c.c. of the liquid. Thus '20 volume' means that 1 c.c. of the solution will yield 20 c.c. of oxygen. If possible buy a small bottle of '20 volume' solution. It is usually kept in dark-glass bottles, because light hastens the decomposition into water and oxygen.

**Bleaching Action.** Put a piece of red or blue litmus-paper and a strand of dark-coloured hair into a test-tube and shake a few drops of hydrogen peroxide in the tube. Both the paper and hair will be bleached.

**Decomposition by Heat.** Warm a few drops of hydrogen peroxide in a test-tube. When effervescence begins plunge a glowing wood spill into the tube. The spill will relight, showing that oxygen is being given off.

An interesting variation of this experiment is to investigate the effect on the rate at which hydrogen peroxide decomposes by the addition of acid or alkali. Put an inch of hydrogen peroxide into each of two test-tubes. To one add a few drops of a solution of an alkali (sodium hydroxide, strong ammonia, etc.) and to the other add a little acid solution (sulphuric acid, citric acid, etc.). Plunge both tubes into a beaker or cup of hot water and after leaving them for a minute or so test both tubes for oxygen. You will find oxygen coming abundantly from the tube containing the alkali but very little from the other. Alkalis speed up the giving off of oxygen, while acids slow it down. For this reason acid is often added to commercial hydrogen peroxide to help it to keep its oxygen.

We have seen previously (p. 62) that a substance which helps a chemical action without being changed itself is called a catalyst. A substance which hinders instead of helping a chemical action is called a 'negative' catalyst. Thus we say that sulphuric acid is a negative catalyst for the decomposition of hydrogen peroxide. Sodium hydroxide and ammonia are 'positive' catalysts.

**Blood and Other Catalysts.** By using suitable catalysts oxygen can be obtained from hydrogen peroxide without any heating at all. Such catalysts include blood, manganese dioxide, ferrous sulphate, and copper sulphate. To obtain a small supply of blood you may have to wait until somebody in the house cuts a finger, when a few drops can be collected in an egg-cup before the injury is bound up. Alternatively you may be able to obtain a little blood from the butcher.

Add the blood to about an inch of hydrogen peroxide in a test-tube and test for oxygen in the usual way. Compare the behaviour of manganese dioxide (from an old flashlight battery, p. 59), ferrous sulphate, and copper sulphate as catalysts.

### 'Hypo'

See Sodium Thiosulphate.

### Iodine

**Chemical Symbol:** I.

Iodine is a non-metallic element. It is really a shiny, black, flaky solid, but is sold as a brown liquid called tincture of iodine for disinfecting cuts. The liquid is a solution containing iodine, potassium iodide, alcohol, and water. It is sold in two strengths, containing 10 per cent. and  $2\frac{1}{2}$  per cent. of iodine respectively. For doing experiments the stronger solution, known to the chemist as 'liquor iodii fortis,' is preferable.

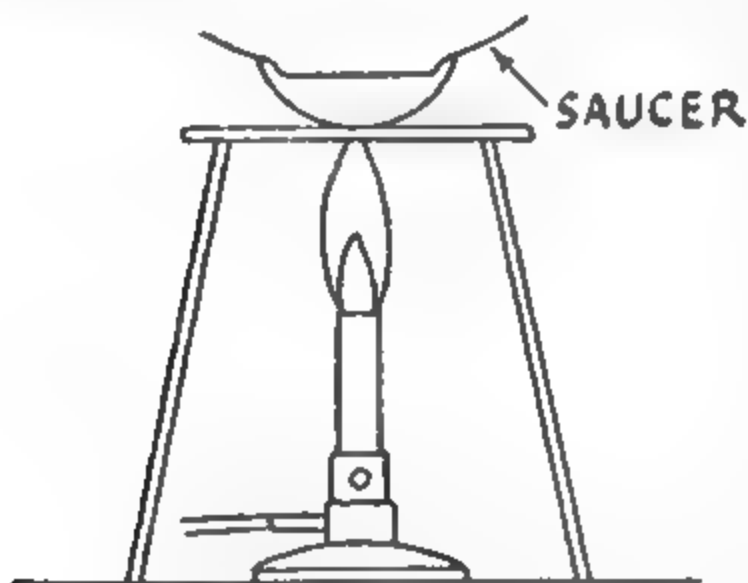


FIG. 26. METHOD OF OBTAINING IODINE CRYSTALS

**Obtaining Solid Iodine from Tincture of Iodine.** Leave half an inch of iodine solution in an egg-cup

to evaporate. When only a few drops of liquid are left in the egg-cup transfer them to an evaporating-dish. Place the dish on a tripod and gauze and place a small saucer over the top, as shown in Fig. 26. Warm the dish over a *small* flame. The remaining liquid will quickly evaporate. Then the iodine will vaporize and become deposited as small shiny black crystals on the bottom of the saucer.

Scrape as many of the crystals as you can from the bottom of the saucer into a dry egg-cup with a penknife. Transfer the crystals to a dry test-tube and warm the tube. The violet vapour of iodine will fill the tube, and shiny black crystals of solid iodine will be deposited again in the cooler part of the tube. Like ammonium chloride (p. 59) iodine does not melt when heated but sublimes. If you wish to keep the iodine crystals you must cork the tube or the iodine will evaporate and disappear.

**Taking Finger-prints with Iodine.** This is a suitable experiment to combine with the previous experiment.

Press your fingers close together on a sheet of plain white paper. While you are vaporizing the iodine from the evaporating-dish in the previous experiment remove the saucer for a few seconds and place the sheet of paper with the finger-prints downward over the



dish. When the paper is removed the prints will show up clearly on the white paper. This method of developing finger-prints—*e.g.*, on cigarettes—is actually used by crime investigators.

**Action with Starch.** The well-known action of iodine with boiled starch solution to give an intense blue colour was described at p. 42. The same substances can be used for making an invisible ink. Write on a sheet of paper with a weak solution of boiled starch and when the writing is dry develop it by brushing over the paper a weak solution of iodine. The writing will stand out in blue-black lettering. The writing will disappear if the paper is warmed, but will return when the paper is cool.

**Decolorizing Iodine Solution.** The method of doing this with sodium thiosulphate solution has already been described (p. 41). Alkalis will also decolorize iodine. Try the effect of adding a few drops of sodium hydroxide, sodium carbonate, or ammonia solution to a little iodine solution.

**Writing on Iron.** Rub the blade of a penknife with sandpaper to clean the surface. Warm the blade and then stroke it on both sides with a small piece of candle or taper. When the blade has cooled a thin coating of wax will be found to have adhered to the metal. Using a knitting-needle, write your initials in the wax. Make sure that you write deeply enough to reach the iron. Cover the blade with iodine solution in a test-tube and leave it for half an hour. When you remove the wax you will find your initials etched on the blade.

### *Iron*

*Chemical Symbol:* Fe.

Iron is a metallic element. It is made into different kinds of steel by mixing it (alloying) with carbon (mild steel) or with metals like manganese (armour-plating steel) or chromium (stainless steel).

**Making Green Vitriol Crystals from Iron Filings.** When iron is treated with dilute sulphuric acid hydrogen gas is given off and a solution of ferrous sulphate (green vitriol) is formed.

Warm half a test-tubeful of dilute sulphuric acid over a small flame, but do not boil the liquid. Remove the tube from the flame and add a few iron filings on the end of a penknife or spill. There will be a vigorous effervescence due to the giving off of hydrogen (test with a lighted spill). When the action dies down add a few more iron filings, and then a few more, until you have added about two saltspoonfuls altogether. Put the tube on one side until effervescence has nearly ceased (about quarter of an hour). Then filter the liquid into an evaporating-dish. Make sure that a little



acid is left, by testing with blue litmus paper. The presence of a little acid prevents the solution from oxidizing to brown ferric sulphate.

To obtain large crystals of ferrous sulphate, leave the solution undisturbed for a day or two to crystallize out. Small crystals can be obtained more quickly by evaporating the solution over a small flame until only about one-third of it remains. If a brown colour appears in the liquid during the evaporation add a drop or two of dilute sulphuric acid. After evaporation allow the remaining liquid to cool. A large number of small crystals of ferrous sulphate will be deposited. The true shape of a ferrous sulphate crystal is shown in Plate 5.

**Heat Treatment of Steel** (a new use for old razor-blades). The properties of steel—whether it is hard, tough, springy, etc.—depend on the manner in which the steel has been treated previously and, in particular, on how it has been heated or cooled. This is shown in the experiments now described. You require three or four old razor-blades, but the experiments can also be performed with steel knitting-needles.

(i) Hold one end of a razor-blade in a pair of pliers and try to bend the other with a pair of pincers. The blade will snap because, although the steel is extremely hard, it is brittle.

(ii) Hold one corner of a razor-blade in a pair of pliers and heat it strongly over a Bunsen flame until it is red hot. When it has been red hot for about half a minute make the flame gradually less hot and smaller, so that the blade cools down very slowly. The gradual cooling should occupy at least five minutes. When the blade is cold it will be found to have lost its hard and brittle character. It can now be bent easily without breaking, and it stays bent. This process of slow cooling is called 'annealing' the steel.

(iii) Straighten the blade used in the foregoing experiment, and once more heat it until it is red hot. Have available some cold water in an old cup or mug. When the blade has been red hot for a short time plunge it into the cold water. You will find that the rapid cooling involved in this treatment has once more made the blade hard and brittle.

(iv) Dry the blade after the quick cooling in experiment (iii) and rub it with emery paper until the surface is bright and clean. Holding the corner of the blade in the pliers, heat it by holding it about an inch above a medium Bunsen flame until a blue sheen just appears over the surface. Allow the blade to cool. It will now be strong and springy. This moderate heating followed by cooling is called 'tempering' the steel.

Iron filings are used in experiments described at pp. 50, 72, and 103.

*Iron Alum*

*Chemical Name:* potassium iron sulphate.<sup>1</sup> *Chemical Formula:*  
 $K_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$ .

Iron alum consists of violet-coloured crystals, which dissolve in water to form a brown solution. The solution is acid to litmus paper. Make a solution by dissolving a saltspoonful of the powdered crystals in two-thirds of a test-tubeful of water. Be careful not to spill the solution (or any other solution containing iron) on to clothes as it causes a brown stain of iron mould, followed by rotting of the cloth.

The experiments here described can also be performed with the solution of ferric sulphate made from ferrous sulphate, as described at p. 75, or with a solution of ferric chloride (p. 74).

**Making Ferric Hydroxide and Ferric Oxide.** To an inch of iron alum solution add about two inches of dilute ammonia solution. Shake the tube to mix the liquids. A brown jelly-like precipitate of ferric hydroxide will be formed.

Filter off the precipitate of ferric hydroxide. Put a little of the reddish-brown jelly left in the filter-paper on to a clean metal lid or into a metal screw-cap. Hold the lid or cap in a pair of pliers and warm it carefully above a small flame. Steam will be given off and a red powder formed. This is ferric oxide, a very pure form of rust. The same substance is obtained by heating green vitriol crystals (p. 75).

**Changing Ferric Sulphate to Ferrous Sulphate.** At p. 75 we saw how green ferrous sulphate could be oxidized to yellow ferric sulphate. The reverse change, of 'reducing' the ferric sulphate in iron alum to ferrous sulphate, can be performed as now described.

Put an inch of iron alum solution into a test-tube with an equal amount of dilute sulphuric acid or sodium bisulphate solution. Add to the mixture a saltspoonful of iron filings or a few small pieces of zinc (obtained from an old flashlight battery). Warm the tube until effervescence, due to the giving off of hydrogen, starts. The hydrogen is the reducing agent. Leave the tube in your test-tube rack for a while. The colour of the solution will gradually vanish. Actually, the liquid left is a very light green. Test it by pouring a little dilute ammonia solution into the tube. A dirty-green, and not a brown, precipitate will now be formed, as in the case of ferrous sulphate (p. 75).

**A Test on Aspirin.** Crush half an aspirin tablet and dissolve the powder by warming it with a little washing-soda solution in a test-tube. Cool the tube under the tap, and make the liquid acid by

<sup>1</sup> Another common form of iron alum is ammonium iron sulphate  $(NH_4)_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$ . It does not matter which form you use.

adding dilute sulphuric acid or sodium bisulphate solution. Now add a few drops of iron alum solution. The liquid will turn a beautiful mauve or violet colour.

**Testing for Tannic Acid in Tea.** When tea has been brewed for a long time it develops a bitter taste, owing to tannic acid dissolved out of the tea-leaves.

Test some tea which has been left standing for a time by pouring one or two drops into a test-tube, diluting with one to two inches of water, and adding a few drops of iron alum solution. A black precipitate of iron tannate will be formed.

**Crystallizing Iron Alum.** The true crystalline form of iron alum is diamond-shaped like that of potash alum and chrome alum. Crystals of the substance in this form can be grown on a piece of cotton, as described at p. 55. The method of growing a large crystal is described in Chapter VII, and a photograph of a large crystal is shown in Plate 4.

### *Lime*

#### (Quicklime and Slaked Lime)

*Chemical Names:* quicklime—calcium oxide; slaked lime—calcium hydroxide. *Chemical Formulæ:* quicklime— $\text{CaO}$ ; slaked lime— $\text{Ca(OH)}_2$ .

The word 'lime' is commonly used for both quicklime and slaked lime, and for convenience we shall consider the substances together. Quicklime is manufactured by roasting chalk or limestone in a lime-kiln. It has the property of giving out a brilliant light when strongly heated, and about fifty years ago was used for lighting stages (hence the phrase "to be in the limelight").

Slaked lime, or calcium hydroxide, is made from quicklime by adding water to the latter. This process is called 'slaking' the quicklime. Slaked lime is used for making lime-water and mortar. It is also used by gardeners to 'sweeten' the soil.

Two pennyworth of quicklime bought from a builder or decorator will supply all the quicklime and slaked lime needed in the experiments described here. It will also give you all the lime-water you are ever likely to use in your experiments. Both forms of lime, however, can be made at home from marble, a small lump of which is generally obtainable at a stonemason's.

**Making Quicklime.** Obtain a lump of marble, chalk (not blackboard chalk), or limestone about twice the size of a thimble, and a length of iron wire about nine inches long. Copper wire is not suitable, as it melts with the heat. The wire used for tying up bundles of firewood answers the purpose. Tie one end of the wire round the lump and hold the other end in a pair of pliers or fasten

it in a metal stand. Place a sheet of asbestos or a metal tray below the Bunsen burner in case the lump falls out of the wire. Suspend the lump just inside a very hot flame (Fig. 27) and heat it for ten to fifteen minutes. In a short time the lump will begin to glow as quicklime is formed. After heating allow the lump to cool on the asbestos or metal tray. Test the quicklime as described in the next experiment.

Another method of making quicklime is to put the lump of marble, chalk, or limestone into a glowing fire with a pair of tongs and leave it there for twenty minutes. Quicklime can also be made from powdered chalk with the help of a home-made blowpipe, as described at p. 122.

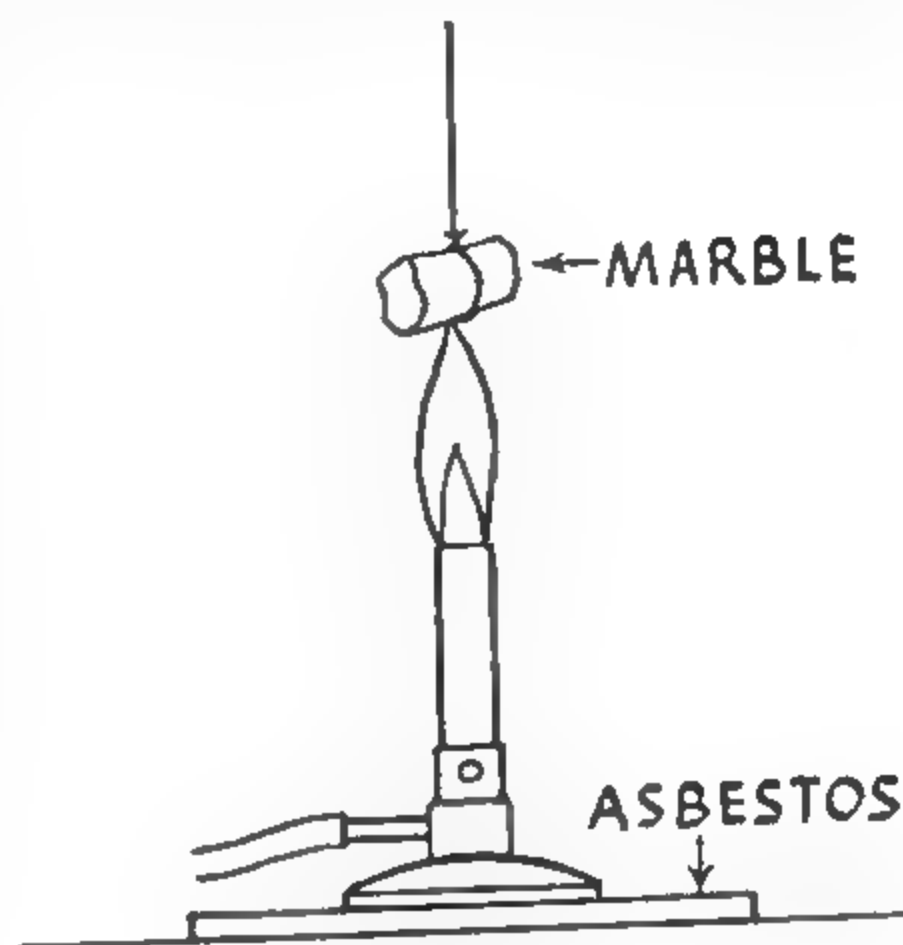


FIG. 27. METHOD OF MAKING QUICKLIME

The making of quicklime from marble, chalk, or limestone is represented by the following chemical action:

Calcium carbonate  $\rightarrow$  calcium oxide + carbon dioxide.

**Testing Quicklime by Slaking.** Put one or two small lumps of fresh quicklime into an evaporating-dish or saucer. By means of a tube add a few drops of water. Clouds of steam will be given off, accompanied by a hissing noise. The quicklime will swell and crack. Continue adding drops of water until no further action occurs. Finally the solid will break up into a fine, *dry* powder. The water has combined chemically with the quicklime, and slaked lime remains.



FIG. 28. THE SLAKING OF QUICKLIME

The word 'quick' in quicklime means 'alive'—as in "the quick and the dead" and 'quicksands.' The superstitious people of the Middle Ages believed that quicklime was inhabited by a spirit. When water was added to it the spirit was released and a dead substance remained. To this day, slaked lime is often called 'killed lime.'

**Making Lime-water.** Slaked lime dissolves to a slight extent in water, and the solution is called lime-water. Shake a teaspoonful of slaked lime with two-thirds of a test-tubeful of water for a minute or two. Filter the milky liquid. The filtrate is lime-water. Test it

with a piece of red litmus paper. The paper will turn blue, showing that lime-water is an alkali. Blow into the lime-water through a glass tube or drinking-straw. The carbon dioxide gas in your breath will turn the lime-water milky.

To keep a supply of lime-water always available put a tablespoonful of slaked lime into a large medicine bottle and fill up the bottle with water. The clear lime-water can be poured off into a smaller bottle as it is required, the large bottle being replenished with water each time.

**To make Mortar.** Measure out one teaspoonful of slaked lime and four teaspoonfuls of clean sand. If you use sea-sand you should wash it three or four times with water to get rid of the salty impurities. Put the slaked lime into an old cup and make it into a paste with water. Stir in the sand a little at a time, adding more water as required, until a stiff paste is formed. Scrape out the paste on to a tin-lid and leave it for a day or two. It will set into a hard mass.

### *Magnesium Sulphate*

*Common Name:* Epsom salts. *Chemical Formula:*  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ .

Magnesium sulphate is a white crystalline substance, which dissolves easily in water forming a neutral solution. It received the name Epsom salts following its discovery in a natural spring of water at Epsom in Surrey in the seventeenth century. The water gained a reputation for its health-giving properties and it became the fashion for members of the aristocracy to journey from London to Epsom to 'drink the waters.' Magnesium sulphate is still used to counteract constipation, either by itself or in many popular brands of health salts.

**Action of Heat.** Warm a saltspoonful of Epsom salts in a dry test-tube over a very small flame. Hold the tube in a paper holder so that it slopes down slightly towards the open end. The water of crystallization in the substance will be given off as steam, which will condense in the cooler part of the tube. The anhydrous magnesium sulphate left in the tube is a white powder. When water of crystallization is driven off from a crystalline substance the latter loses its crystalline form and is left as a powder. This effect has already been noted with copper sulphate (p. 46).

**Action of Ammonia.** Add some dilute ammonia solution to a solution of magnesium sulphate. A white precipitate of magnesium hydroxide will be formed.

**Action of Sodium Carbonate.** Add an inch of sodium carbonate solution to an inch of magnesium sulphate solution in a test-tube. A white precipitate of magnesium carbonate will be produced. The chemical action is one of double decomposition. Thus:



Magnesium sulphate + sodium carbonate  $\rightarrow$   
magnesium carbonate + sodium sulphate.

The precipitate is readily soluble in acids. If a few drops of any acid solution are added to the test-tube the precipitate will disappear.

**A Test for Magnesium in Compounds.** Pour two or three drops of magnesium sulphate solution on to a filter-paper and then two or three drops of cobalt chloride solution. Warm the wet paper over a small flame until it is dry and then set fire to it. Hold the burning paper over a saucer to catch any ash which drops. The ash will have a pink colour. The same result is obtained with any solution which contains magnesium.

**Crystallizing Epsom Salts.** This experiment can be carried out as described for copper sulphate at p. 38. A beautiful show of needle-shaped crystals will be obtained (see Plate 4).

### *Manganese Dioxide*

*Chemical Formula:*  $\text{MnO}_2$ .

This chemical is a black powder closely resembling carbon in appearance. It can be distinguished from carbon by the fact that it does not burn away when heated on a metal lid. Manganese dioxide is contained in flashlight batteries and other forms of dry-cells. It is easily obtained from this source, as described at p. 59.

In Chemistry manganese dioxide is chiefly used in the preparation of chlorine gas (p. 91) and as a catalyst in the preparation of oxygen (p. 77). It gives a wine-coloured borax bead (p. 120).

### *Nitric Acid (Dilute)*

*Chemical Formula:*  $\text{HNO}_3$ .

Acids are usually divided into two groups—organic acids and mineral acids—according to how they are obtained. Organic acids are generally obtained from plant or animal sources. Thus citric acid can be made from lemons (p. 103) and lactic acid from milk (p. 106). They are weak acids, and in dilute solution can be safely consumed, as in the case of the acetic acid in vinegar.

Mineral acids are usually prepared from minerals obtained from the ground. This class includes nitric acid, sulphuric acid, and hydrochloric acid. Nitric acid itself was formerly made from sodium nitrate, but is now manufactured from the nitrogen of the air. In contrast to organic acids, nitric acid and most other mineral acids are very strong acids and extremely corrosive to flesh, clothing, carpets, etc. The concentrated acids are too dangerous for boys to use in carrying out experiments at home.



A small amount of dilute nitric acid can usually be obtained from a chemist's if you present a note signed by a parent. Even the dilute acid is corrosive if left on clothes. Acid which has been accidentally spilled should be neutralized with *dilute* ammonia solution, the part affected being tested with red litmus paper until the latter turns blue. The dilute acid is also poisonous, and suitable precautions should be taken in performing experiments with it.

**Dilute Nitric Acid dissolves Metals.** Put a few strands of copper wire from an old electric light flex into a test-tube with about an inch of dilute nitric acid. Warm the tube gently until effervescence starts and then stand the tube in your test-tube rack or a jam-jar. The effervescence is caused by the giving off of oxides of nitrogen, principally nitric oxide,  $\text{NO}$ , and nitrogen peroxide,  $\text{NO}_2$ . The first of these gases is colourless, while the second consists of brown fumes. In a few minutes the copper will have dissolved in the acid and a greenish-blue solution of copper nitrate will be left.

In a similar way iron filings and zinc can be dissolved in dilute nitric acid to give solutions of ferrous nitrate and zinc nitrate.

**Dilute Nitric Acid dissolves Metal Oxides.** Warm a pinch of black copper oxide with about an inch of dilute nitric acid in a test-tube. The copper oxide will disappear and a blue solution of copper nitrate will be formed.

**Dilute Nitric Acid liberates Carbon Dioxide from Carbonates and Bicarbonates.** Put half an inch of chalk (calcium carbonate), washing-soda (sodium carbonate) or baking-soda (sodium bicarbonate) into a test-tube and add a few drops of dilute nitric acid. There will be a vigorous effervescence due to the giving off of carbon dioxide. Test the gas with lime-water as described at p. 43.

**Making Sodium Nitrate Crystals by Neutralization.** This experiment is similar to the preparation of ammonium sulphate by neutralization, as described at p. 57. Dilute nitric acid is used instead of dilute sulphuric acid, and either sodium carbonate or sodium hydroxide solution can be used as the alkali.

Other experiments in which dilute nitric acid is used are described at pp. 71, 95, and 144.

### *Salt (Common)*

See Sodium Chloride.

### *Sodium Bicarbonate*

*Common Names:* baking-soda, bicarbonate of soda. *Chemical Formula:*  $\text{NaHCO}_3$ .

Sodium bicarbonate is a soft white powder. It dissolves to only a small extent in cold water, and it is decomposed by hot water. The

solution is a very weak alkali. It turns red litmus blue, but is too weak an alkali to affect phenolphthalein.

A chemist always keeps a supply of sodium bicarbonate at hand in his laboratory, because it is a very useful chemical. It is the best substance to use for neutralizing acid splashes on the skin. The part affected is made wet with water and a little of the white powder is rubbed on. Acid splashes in the eye are treated by quickly mixing a saltspoonful of sodium bicarbonate with a egg-cupful of lukewarm water and applying the egg-cup to the eye. The solution is also a good first-aid treatment for ordinary burns.

Among the many uses of sodium bicarbonate in everyday life might be mentioned its use in baking-powder (a mixture of sodium bicarbonate with an acid substance like cream of tartar), effervescing health salts, and chemical fire-extinguishers (see p. 136).

**Decomposing Baking-soda by Heat.** Put half an inch of sodium bicarbonate into a dry test-tube. Have ready another test-tube containing an inch of clear lime-water. Hold the first tube in a paper holder in your left hand so that the tube slopes down, and hold the lime-water tube in the other hand so that the tubes are mouth to mouth. Warm the baking-soda over a *very small* flame.

Notice that moisture is deposited in the cooler part of the tube. After warming for a couple of minutes lay the heated tube on a gauze, and shake up the lime-water. This will turn milky, showing that carbon dioxide has been given off. The chemical action which has taken place can be written:

Sodium bicarbonate  $\rightarrow$  sodium carbonate + water + carbon dioxide.

**Action of Acids.** Any acid solution causes carbon dioxide to be given off very readily from sodium bicarbonate. You can try this in a test-tube. An alternative method is to put a teaspoonful of baking-soda into a jam-jar and add a little vinegar or other acid. If a lighted taper or spill is introduced into the jar it will be extinguished by the carbon dioxide formed.

**Obtaining Precipitates with Sodium Bicarbonate.** A solution of sodium bicarbonate gives precipitates with solutions of various metal salts. These precipitates are not bicarbonates but the ordinary carbonates of the metals. Try this by putting about an inch of baking-soda solution into a test-tube and adding a few drops of any of the following solutions: copper sulphate, ferrous sulphate, magnesium sulphate, zinc sulphate.

**Testing for Sodium Bicarbonate in Maclean Brand Stomach Powder.** This mixture contains calcium carbonate,

magnesium carbonate, bismuth carbonate, and sodium bicarbonate. Of these, only sodium bicarbonate is soluble.

Shake a teaspoonful of the powder with an inch of water in a test-tube for a minute or two. Filter the milky liquid. The filtrate will be a colourless solution of sodium bicarbonate. Dip the end of a wood spill into the liquid and hold it in the edge of a non-luminous Bunsen flame. The flame will turn an intense yellow colour (test for sodium). Warm the rest of the solution. Carbon dioxide will be given off, as shown by lime-water (test for a bicarbonate).

**Preventing Milk from going Sour.** In hot weather milk often turns sour, because bacteria change the milk-sugar into an acid (lactic acid). Milk which is just beginning to 'go off' can be saved by adding a little sodium bicarbonate to it. Use a saltspoonful of the substance to a pint of milk.

**Preparing Washing-soda Crystals from Baking-soda.** Put two teaspoonfuls of baking-soda into a beaker which is about one-third full of water. Stir the powder round. Pour off a few drops of the liquid into a test-tube and test it with a drop of phenolphthalein, to show that sodium bicarbonate solution is too weak an alkali to give the usual red colour with this indicator. Heat the beaker on a gauze and tripod and keep the liquid gently boiling for ten minutes. The sodium bicarbonate will soon disappear because it is decomposed into sodium carbonate (which is much more soluble), water, and carbon dioxide.

Allow the beaker to cool. Test a few drops of the liquid again with a drop of phenolphthalein. A rose-red colour will now be produced, showing that sodium carbonate is a stronger alkali than sodium bicarbonate. If colourless crystals of washing-soda have not been deposited by the time the beaker is cold, transfer the solution to an evaporating-dish and leave it for a time in a warm place.

Other experiments in which baking-soda is used are described at pp. 48, 56, 71, 91, 136, and 149.

### *Sodium Bisulphate*

*Chemical Formula:*  $\text{NaHSO}_4$ .

This is a white crystalline substance, which is very soluble in water and gives an acid solution. The crystals are deliquescent: when exposed to air they absorb moisture, become wet, and eventually form a solution. The crystals should therefore be kept in a well-stoppered bottle.

Sodium bisulphate is a useful substance to have in your stock of chemicals, because the solution can be used in most experiments as a substitute for dilute sulphuric acid, which is sometimes difficult to obtain. Some preparations in Chemistry normally require the use

of concentrated sulphuric acid, a chemical which is very dangerous except when used by experienced chemists. In its place you can often employ crushed solid sodium bisulphate.

Both the solid and the solution are corrosive, and care should be taken to avoid spilling either. If spilling does occur, wipe up the spilled material immediately with a wet cloth and neutralize any remaining acid with *dilute* ammonia or baking-soda until there is no longer an acid reaction with blue litmus paper. Do not use ammonia on your skin.

Sodium bisulphate is mentioned in many experiments in this book (see also Sulphuric Acid, p. 98).

### *Sodium Carbonate*

*Common Name:* washing-soda. *Chemical Formula:*  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ .

Washing-soda is a very common chemical. It consists of colourless or white crystals. Well over half of the weight of the crystals is due to the water of crystallization. Washing-soda dissolves readily in water, and the solution is a fairly strong alkali. If the solution is left on the skin it may produce blisters. Washing-soda is used at home because it removes grease and softens hard water (p. 131). It is also a constituent of washing-powders and bath salts.

**A Well-known Property of Washing-soda.** Pick out a large, clear crystal of washing-soda and leave it on a saucer for about an hour. It will then be found to have acquired a white powdery coating which can easily be scraped off with a knife. This change is called 'efflorescence,' and it is caused by the crystal losing some of its water of crystallization to the air. The white powder has the chemical formula  $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ , and is sometimes called sodium carbonate monohydrate.

**Action of Heat.** Warm a crystal of washing-soda gently on a tin-lid or in a metal screw-cap. The crystal will quickly melt. When the heating is continued clouds of steam are given off, the liquid dries up, and a white powder remains. The substance has now lost all its water of crystallization and is anhydrous sodium carbonate. The latter is known commercially as soda-ash.

**Action of Acids.** When sodium carbonate is treated with an acid there is effervescence, due to the giving off of carbon dioxide, and the sodium carbonate dissolves. Try in turn the action of vinegar, citric acid, dilute sulphuric acid, etc., on a few washing-soda crystals.

**Obtaining Precipitates with Washing-soda.** In Chemistry a solution of sodium carbonate is used to make precipitates of other metal carbonates. Add some washing-soda solution to small amounts of solutions of copper sulphate, ferrous sulphate, magnesium sulphate,

and zinc sulphate. The action in each case is a double decomposition, and in the case of zinc sulphate can be written:



With a solution of alum or aluminium sulphate the sodium carbonate precipitates aluminium hydroxide—not aluminium carbonate. This is because aluminium carbonate is a very unstable substance and is at once decomposed by the water into the hydroxide.

**A Red Invisible Ink.** Write on paper with a solution of phenolphthalein. Allow the paper to dry, when the writing will be invisible. Wet a cloth or sponge with weak sodium carbonate solution and smear it over the paper. The writing will at once show up in red letters.

**Making Baking-soda from Washing-soda.** Fix up the apparatus shown at p. 64 (see also p. 173) for delivering carbon dioxide. Make a strong solution of sodium carbonate by warming two teaspoonfuls of powdered washing-soda crystals with a test-tubeful of water in a beaker. Half fill a test-tube with the strong solution and cool it under the tap.

Put the delivery-tube from the carbon dioxide apparatus to the bottom of the solution in the test-tube and pass a slow stream of carbon dioxide through the liquid for about ten minutes. A white precipitate of sodium bicarbonate will be formed. Filter the precipitate, and dry it by leaving the filter-paper opened out on a piece of newspaper in a warm place. Test the product by heating it as described under Sodium Bicarbonate and testing for carbon dioxide being given off.

The course of the chemical action in this experiment can be followed if a drop of phenolphthalein solution is added to the washing-soda solution in the test-tube. A red colour is imparted to the solution. The colour will disappear when all the sodium carbonate has been converted into sodium bicarbonate.

**Making Bath Salts.** These crystals are often added to bath water to 'soften' it (p. 130). Washing-soda crystals coloured by dyes are sometimes sold as a cheap form of bath salts. When exposed to the air they betray their identity by acquiring the usual white coating due to efflorescence, as described previously.

Better quality bath salts consist of crystals of sodium sesquicarbonate, and have the chemical formula



They are made by combining washing-soda and baking-soda together, colouring-matter and perfume being added to make the



product more attractive. These crystals are not so strongly alkaline in solution as washing-soda, which tends to remove not only the dirt but the skin as well!

To make bath salt crystals, dissolve a small, level teaspoonful of baking-soda in an egg-cupful of warm (but not hot) water in a beaker. When it has dissolved add four times as much powdered washing-soda, and dissolve this also. Transfer the solution to an evaporating-dish and leave this in a warm place until crystals have formed. It will be found that, unlike washing-soda, these crystals are not efflorescent.

### *Sodium Chloride*

*Common Name:* salt. *Chemical Formula:* NaCl.

Salt is a white crystalline substance composed of sodium (a metal) and chlorine (a gas). Grains of salt consist of tiny cubes, as can be seen by examining a few grains from a salt-cellar through a magnifying glass. Salt dissolves readily in water to give a neutral solution often called brine. Besides its uses at home for cooking and flavouring, salt is used in large quantities for making butter, curing fish, and manufacturing important chemicals like washing-soda.

**A Flame Test.** When introduced into a flame salt imparts a brilliant golden-yellow colour to it (p. 47). This is the chemical test for sodium in a substance. 'Sodium-vapour' lamps are used for lighting roads in some towns. The yellow light of sodium makes a person's face appear bloodless and ghost-like.

**Showing the Insolubility of Salt in Methylated Spirit.** This experiment can be carried out as described for copper sulphate (p. 72).

**Making Hydrochloric Acid Gas from Salt.** Mix together two saltspoonfuls of salt and an equal amount of powdered alum, ferrous sulphate or sodium bisulphate. Put the mixture into a dry test-tube and have ready a damp blue litmus paper and a bottle of strong ammonia. Heat the mixture over a medium Bunsen flame, holding the tube in a paper holder and moving the tube about in the flame.

Hydrochloric acid gas, or hydrogen chloride, will soon be given off in the form of steamy fumes. Sniff the gas cautiously and put the blue litmus paper into the fumes. Test the gas, also, by removing the stopper from the bottle of strong ammonia and blowing the steamy fumes across the top of the bottle (Fig. 29). A dense white smoke will be produced. The white smoke consists of ammonium chloride.

**Making Chlorine Gas from Salt.** Again make a mixture of equal parts of salt and powdered alum, ferrous sulphate, or sodium bisulphate, and then mix in an equal part of black manganese



dioxide. Have ready a piece of damp litmus paper (red or blue). Heat the mixture over a medium Bunsen flame, holding the tube in a paper holder. Chlorine, a green gas with a choking smell, will be formed in the tube. Sniff the gas very cautiously and test it with the litmus paper. The latter will be bleached (turned white). This is the usual test for chlorine.

**Crystallizing Salt in Cubes.** Make a saturated solution of salt by warming an inch of salt with half a test-tubeful of water to which

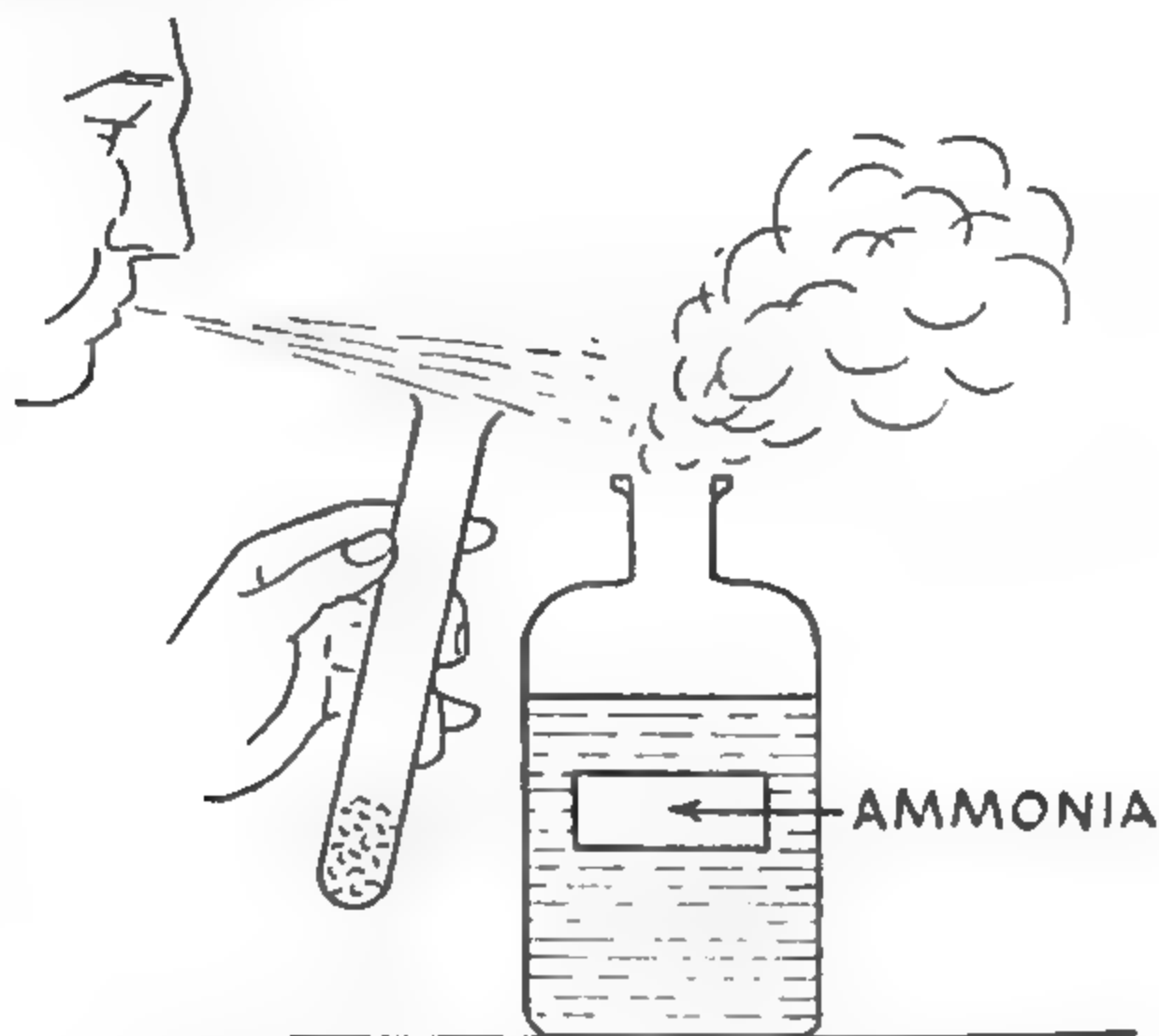


FIG. 29. METHOD OF TESTING HYDROCHLORIC ACID GAS

has been added a drop of dilute sulphuric acid or four or five drops of citric acid solution (or lemon juice). Cool the tube under the tap. Filter a third of the solution into a small glass pot of the kind used for fish-paste. Leave the pot for twenty-four hours in a warm place. A number of crystals of salt will then be found at the bottom of the pot. If an electric torch is shone up through the bottom of the pot, the cubical shape of the crystals will be clearly seen.

### *Sodium Hypochlorite*

*Common Name:* bleaching fluid. *Chemical Formula:*  $\text{NaOCl}$ .

This chemical does not exist in solid form. It is sold as a strong solution by chandlers under various trade names, such as Chloros, for bleaching and for disinfecting sinks and drains. A very weak solution is sometimes used as a gargle (*e.g.*, Milton). Strong solutions of the chemical are poisonous.

**Bleaching Experiments.** Wet the cork of the bottle of bleaching

fluid with the strong solution and dab it on a piece of red litmus paper. The paper will first be turned blue and then bleached.

Put one drop of ordinary blue-black ink into a test-tube and fill the tube up to half-way with water. Now add one drop of bleaching fluid and shake the tube. The colour of the liquid will be at once destroyed. A method of making your own ink-eradicator is described at p. 51.

To show the bleaching of cloth, a strip of coloured cotton cloth is best. Wet the cloth under the tap and squeeze it out. Place the cloth in a jam-jar and add to the jar half a test-tubeful of the strong bleaching fluid and two test-tubefuls of water. Leave the cloth in the liquid for twenty-four hours. If by then the colour has not completely disappeared, renew the bleaching solution and leave the cloth in it again. The cloth will be rotted if too strong a bleaching solution is used.

**Oxygen from Bleaching Fluid.** Put about an inch of bleaching fluid into a test-tube and add a crystal of cobalt chloride. The contents of the tube will turn black. Warm the tube gently over a small flame. Effervescence will soon begin and oxygen will be given off in abundance. Test for the oxygen by introducing a glowing wood spill into the mouth of the tube.

**Chlorine from Bleaching Fluid.** Add a few drops of any acid solution (citric, tartaric, sulphuric acid, etc.) to a few drops of bleaching fluid in a test-tube. The green gas chlorine will be given off without any heating. Sniff the gas cautiously and test it with a piece of wet litmus paper. The paper will be bleached by the chlorine.

**Making Sodium Hypochlorite from Chloride of Lime and Washing-soda.** Make a fairly strong solution of washing-soda by dissolving two teaspoonfuls of the powdered crystals in half a cupful of hot water. Allow the solution to cool. Put two teaspoonfuls of chloride of lime (bleaching powder) into a beaker and add the cold solution of washing-soda, stirring round with a glass rod. When all the washing-soda has been added allow the white solid (chalk) in the beaker to settle. Then pour off and filter the liquid which is above the solid. The filtrate is a solution of sodium chloride and sodium hypochlorite, and can be tested by means of the experiments previously described.

Bleaching fluid is used in experiments described at pp. 177, 187.

### *Sodium Hydroxide*

*Common Name:* caustic soda. *Chemical Formula:* NaOH.

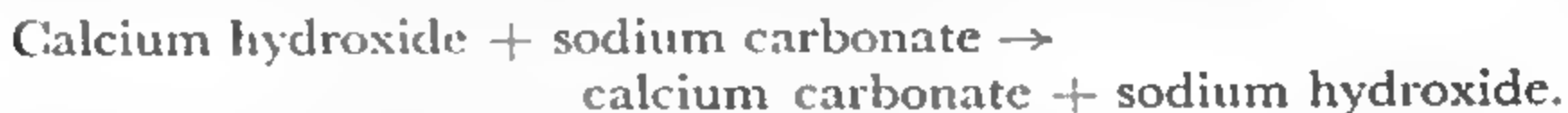
Sodium hydroxide is a white deliquescent solid, attracting moisture from the air and forming a solution. It should be stored in a bottle,

with a tightly fitting cork or rubber stopper. Glass stoppers or metal screw-caps tend to become cemented to the glass. Caustic soda is sold by ironmongers for cleaning cookers and by paint shops for removing old paint. *On no account must the solid or solution be handled.* Sodium hydroxide is a strong alkali with a powerful caustic action if left on skin. It destroys the skin and causes painful blisters. Clothing also is corroded by caustic soda. Accidental splashes of the solution should first be treated with water if the solution is strong and then neutralized with vinegar, citric or tartaric acid (but not sulphuric or other mineral acid), the part affected being tested with red litmus paper until it fails to turn blue.

Sodium hydroxide should always be used in dilute solution. For stock purposes put half a teaspoonful of the solid into a beaker half full of water and stir with a glass rod or stick until the solid has dissolved. Transfer the solution to a bottle and cork it securely. Instead of buying sodium hydroxide, you can make it, as now described.

**Making Sodium Hydroxide Solution from Slaked Lime and Washing-soda.** Fill a beaker half full of water and heat it on a gauze and tripod until the water boils. Add a tablespoonful of powdered washing-soda and stir until it has dissolved. Now add half a tablespoonful of slaked lime (calcium hydroxide) and continue the boiling. After about five minutes filter a few drops of the hot liquid into a test-tube and test the filtrate by adding a few drops of any acid solution. If there is no effervescence the action is complete. If effervescence occurs add another teaspoonful of slaked lime to the beaker and continue the boiling for another five minutes. Then test in the same way.

When testing shows that there is no sodium carbonate in the filtrate leave the beaker to cool. The white residue of chalk will settle on the bottom of the beaker. When the beaker is cool pour off the clear solution of sodium hydroxide (do not filter it) into your stock bottle, and, as the solution is rather strong, add an equal amount of water. The chemical action which occurs in this experiment is a double decomposition, and can be written:



**The Soapy Feel of Caustic Soda.** Moisten the tip of a finger with a drop of dilute sodium hydroxide solution and rub your fingers together for a moment. The soapy feel is a typical property of strong alkalis. Wash your fingers immediately after doing the test.

**Action on Ammonium Salts.** Warm a saltspoonful of ammonium chloride, carbonate, or sulphate with a few drops of caustic

soda solution. Ammonia gas will be given off. It can be tested by smell and by the turning blue of damp red litmus paper.

**Making a Salt by Neutralization.** As sodium hydroxide is an alkali, it can be used to neutralize an acid. The substance resulting from the neutralization is a salt. The action can be represented:



For this experiment a solution of citric acid, dilute nitric acid, or dilute sulphuric acid can be used. The salt obtained will be sodium citrate, sodium nitrate, or sodium sulphate. The details of the preparation are similar to those described for making ammonium sulphate (p. 57).

**Obtaining Metal Hydroxides by Precipitation.** Like ammonia sodium hydroxide is used in Chemistry to make metal hydroxides from solutions of metal salts.

Put small amounts of the following solutions into test-tubes and add dilute caustic soda to each: alum, copper sulphate, ferrous sulphate, ferric chloride, or iron alum, magnesium sulphate, zinc sulphate. Various colours of precipitates will be formed. The hydroxides of aluminium and zinc will dissolve if a further amount of caustic soda solution is added and the tube shaken.

**Making Washing-soda Crystals from Caustic Soda.** This experiment requires an apparatus which will deliver a steady stream of carbon dioxide (see pp. 64 and 173). The preparation can be carried out with an ordinary test-tube, using only one-third of a test-tubeful of caustic soda solution, but it is best done as follows.

Measure out a test-tubeful of dilute caustic soda solution and transfer it to a boiling-tube. Pass a slow, steady stream of carbon dioxide into the solution for five minutes, taking care that the delivery-tube is at the bottom of the liquid. Some of the gas will be absorbed by the solution. Put the remaining solution into an evaporating-dish and evaporate it over a small flame until about one-third of it remains. Then leave the solution to crystallize. Large colourless crystals of washing-soda, sodium carbonate, will be formed.

### *Sodium Silicate*

*Common Name:* water-glass. *Chemical Formula:*  $\text{Na}_2\text{SiO}_3$ .

Sodium silicate is a glassy solid usually sold in strong solution as a thick syrupy liquid. It dissolves in water to form an alkaline solution. It is used for preserving eggs and for fireproofing fabrics. It is also one of the chief constituents of ordinary window-glass (see p. 124).

**Obtaining Precipitates with Sodium Silicate.** When a

solution of water-glass is added to solutions of certain metal salts precipitates of metal silicates are formed.

Put into test-tubes small amounts of the following solutions: alum, copper sulphate, ferrous sulphate, ferric chloride or iron alum, cobalt chloride, nickel sulphate. Make a solution of sodium silicate by stirring a teaspoonful of water-glass in half a beakerful of warm water. Add a little of this solution to each of the test-tubes. Note the different colours of the precipitates which are formed.

**Making a Chemical Garden.** This is a very well-known and interesting experiment which you can easily perform for yourself at home.

Make a strong solution of sodium silicate by dissolving two tablespoonfuls of water-glass (it is quicker actually to use two spoons)

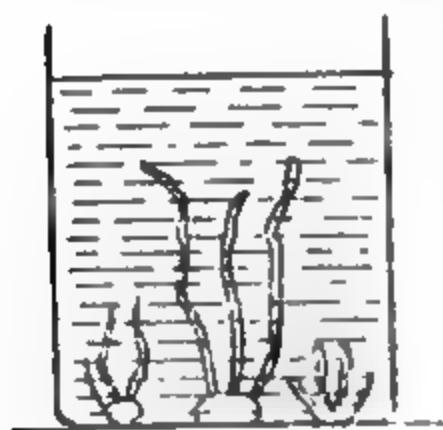


FIG. 30. A  
CHEMICAL GARDEN

in a cupful of hot water. Transfer the solution to a beaker or jam-jar and allow it to cool. When the solution is quite cold drop into the jar small crystals of four or five of the chemicals mentioned in the previous experiment and leave the jar undisturbed on a shelf. After a time the crystals will look as if they are sprouting. Growths from the crystals rise up through the liquid and give the appearance of plants growing in the solution.

**Making Silicic Acid and Pure Silica.** Silica is another name for sand, but ordinary sand is an impure form of silica. White sand is almost pure silica. The white silica can be made from water-glass, as here described.

Prepare strong solutions of sodium silicate and sodium bisulphate. For the former dissolve a teaspoonful of water-glass in a third of a cupful of warm water. The sodium bisulphate solution is made with a teaspoonful of the crystals and about an inch of water in a test-tube. Mix the solutions together in a beaker. A jelly-like precipitate of silicic acid will be formed. Filter off the gelatinous precipitate, and wash it by running a little warm water through the filter-paper. Scrape the precipitate out of the filter-paper with a spoon into a metal screw-cap or on to a tin-lid. Hold the screw-cap or lid in a pair of pliers and heat it. The fine white powder left is pure silica. Its chemical formula is  $\text{SiO}_2$ .

### *Sodium Sulphate*

*Common Name:* Glauber's salt. *Chemical Formula:*  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ .

This is a white crystalline substance, used, like Epsom salts, as a laxative. The crystals resemble washing-soda in being efflorescent—that is, they lose water of crystallization when exposed to air and



become covered with a white powder. The crystals dissolve readily in water and give a neutral solution.

**Making a Supersaturated Solution.** This experiment is done with a 'supersaturated' solution of Glauber's salt. A supersaturated solution is a chemical curiosity. It is a solution which contains more of the dissolved substance than is normally needed to make a saturated solution at the given temperature.

Half fill a clean empty ink-bottle with Glauber's salt and add water until the crystals are covered with a quarter of an inch of water. Put the bottle (without stopper) into a saucepan with about an inch of cold water and heat the saucepan on a gas-ring. When the water begins to boil turn the flame down, but keep the water just boiling until the crystals dissolve (ten minutes). Ignore any white specks left. Now put a plug of cotton-wool into the neck of the bottle to exclude dust, and leave it to cool on a saucer outside in the open air (twenty minutes). When cold the contents of the bottle will remain liquid. You now have a supersaturated solution. Remove the cotton-wool and at once drop a small crystal of Glauber's salt into the bottle. Long spiky crystals will shoot out in all directions from the crystal added and the liquid will become almost solid.

### *Sodium Thiosulphate*

*Common Name:* 'hypo.' *Chemical Formula:*  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ .

Sodium thiosulphate consists of colourless crystals, which dissolve in water to give a neutral solution. It is a well-known chemical because of its use in photography. It is used in the process of 'fixing'—that is, dissolving silver bromide off the exposed plate or film.

**Action of Heat.** Heat a few crystals of sodium thiosulphate in a dry test-tube, holding the tube in a paper holder. The crystals will first melt and give off their water of crystallization. With stronger heating a yellow deposit of sulphur will be formed in the cooler part of the tube and there will be a smell of hydrogen sulphide, the 'bad egg' gas.

Allow the tube to cool. The remaining substance consists largely of sodium sulphide. Moisten it with a few drops of any acid solution. A very strong smell of hydrogen sulphide will now be noticed.

**Action of Acids.** Warm a few crystals of 'hypo' in a test-tube with a little citric acid solution or dilute sulphuric acid. Sulphur dioxide gas, which has a sharp, choking smell, will be given off and a milky precipitate of sulphur will be formed in the tube. If a piece of damp blue litmus paper is held at the open end of the tube it will be turned red, as sulphur dioxide is an acid gas.

**Action on Copper Sulphate Solution.** Make a strong solution



of 'hypo' by warming about a dozen crystals with an inch of water in a test-tube. Cool the solution under the tap. Add to the test-tube, drop by drop, about an inch of copper sulphate solution. The blue colour of the copper sulphate solution will be destroyed as it mixes with the 'hypo.' Now heat the mixture until it begins to boil. Remove the tube from the flame and watch the liquid. It will slowly turn yellow, then brown, and finally a heavy black precipitate will form. The precipitate is copper sulphide.

**Making a Supersaturated Solution.** Like Glauber's salt 'hypo' readily forms a supersaturated solution. The following is an interesting method of showing the property.

Add two drops of water to about an inch of 'hypo' crystals in a test-tube and warm the tube gently over a small flame. When the crystals have turned into liquid put a plug of cotton-wool in the mouth of the tube and leave it until *nearly* cold. The contents of the tube will remain liquid. Remove the cotton-wool and pour out the liquid on to a sheet of clean glass or a small mirror. Now drop into the middle of the pool of liquid a tiny crystal of 'hypo.' Crystals will shoot out in all directions from the tiny crystal and the whole of the liquid will turn into solid.

### *Sulphuric Acid (Dilute)*

*Chemical Formula:*  $\text{H}_2\text{SO}_4$ .

Like nitric acid sulphuric acid is a mineral acid. Pure sulphuric acid is a heavy oily liquid called oil of vitriol or sometimes just vitriol. In this form it is a very dangerous chemical, on account of its strong corrosive properties, and should not be used for experiments at home.

Dilute sulphuric acid can usually be bought in small amounts at a chemist's, although a parent's note may be required if you are below the age of 16. The sulphuric acid used in wireless accumulators and motor-car batteries is suitable for carrying out experiments if it is first diluted with water to about four times its volume. Care should be taken in handling even dilute sulphuric acid, as it is poisonous and corrosive if left on clothes, carpets, etc. In most experiments a solution of sodium bisulphate (p. 88) can be used instead of sulphuric acid.

The properties of dilute sulphuric acid are illustrated by experiments described in various parts of this book. These properties can be summarized as follows:

(i) It dissolves metals like iron (p. 50) and zinc (p. 99) but not copper. The failure to dissolve copper distinguishes this acid from dilute nitric acid (p. 86).

- (ii) It dissolves metal oxides, like copper oxide (p. 72).
- (iii) It is neutralized by alkalis, like ammonia solution (p. 57).
- (iv) It liberates carbon dioxide gas from metal carbonates and bicarbonates (pp. 87, 89).

### *Washing-soda*

See Sodium Carbonate.

### *Water-glass*

See Sodium Silicate.

## *Zinc*

*Chemical Symbol:* Zn.

Zinc is a metallic element. It is readily obtained in the form of foil from a spent dry-cell or flashlight battery (see p. 196). For some experiments a more convenient form of the metal is zinc powder, which can be bought cheaply. Zinc is extensively used in galvanizing iron sheets—that is, covering the iron with a layer of zinc to prevent the iron from rusting. Brass is an alloy of copper and zinc.

**Burning of Zinc.** This can be done in two ways, but both require the use of zinc powder. Sprinkle a little of the powder into a non-luminous Bunsen flame. The particles will burn with a fine display of green flashes.

Put a teaspoonful of zinc powder into an egg-cup and stir it up with two or three drops of sodium hydroxide solution so that a thick paste is formed. Transfer the paste with an old spoon to a filter-paper placed on a newspaper and press the paste between the filter-paper to squeeze out most of the moisture. Now put the damp cake on a metal lid and leave it in the air for a few minutes. Shortly clouds of steam will arise and the mass will turn yellow as the zinc combines with oxygen from the air to form zinc oxide. It may be five or ten minutes before the zinc sets on fire, but it will do so eventually. The zinc oxide will turn white as it cools.

**Action of Acids.** Zinc causes hydrogen to be given off from most acids. Try this with vinegar, citric acid, tartaric acid, dilute sulphuric acid, etc., using not more than one inch of the acid solution in a test-tube. Test for the hydrogen with a lighted taper or spill. With powdered zinc the action is vigorous even in the cold. With zinc foil it is necessary to warm the acid, and the action is greatly speeded up by adding a drop of copper sulphate solution to the tube.

**Action with Alkali.** Warm a few small pieces of zinc foil with an inch of sodium hydroxide or sodium carbonate solution in a test-tube. Hydrogen will be given off (test as in the previous experiment). With powdered zinc the action is rather violent, and only a few drops of the alkali solution should be used.

**Combination with Iodine.** Shake a few small pieces of zinc foil or a little zinc powder with an inch of iodine solution in a test-tube. The colour of the iodine will gradually disappear, because the metal combines with the iodine to form a solution of zinc iodide. Pour off the liquid which remains and add to it a few drops of sodium carbonate solution. A white precipitate of zinc carbonate will be produced.

**Displacement of Copper from Copper Sulphate.** Rub a strip of zinc foil with sandpaper to clean the surface. Add the zinc to a little warm copper sulphate solution. A red deposit of copper will be formed on the zinc. The chemical action can be written:



### *Zinc Sulphate*

*Common Name:* white vitriol. *Chemical Formula:*  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ .

Zinc sulphate consists of white crystals, which dissolve in water to give a slightly acid solution. A very weak solution is sometimes used as an eye-lotion. Solutions of zinc sulphate are poisonous.

**Making Zinc Sulphate Crystals from Zinc.** Cut some zinc foil into small pieces. Put about half an inch of these pieces into a test-tube with about half a test-tubeful of dilute sulphuric acid. Warm the tube until effervescence begins and then leave the tube standing in a test-tube rack or a jam-jar. If the zinc is very pure it may dissolve only slowly. In this case add one or two drops of copper sulphate solution to the tube. This will make the zinc dissolve much more quickly.

Leave the tube until effervescence has stopped. Some zinc should still be present in the tube, showing that all the acid has been used up. You will probably see small black specks floating about in the liquid. These are specks of carbon, a common impurity in zinc. Filter the solution into an evaporating-dish and evaporate the filtrate until about one-third of the liquid remains. When the solution is left to crystallize small white crystals of zinc sulphate will be formed. These can be dried by pouring away the liquid and scraping the crystals on to a piece of blotting-paper or filter-paper which is then left on a newspaper in a warm place.

**Action of Heat.** Warm some zinc sulphate crystals in a metal screw-cap. Water of crystallization will be given off and the substance will lose its crystalline form and change into a white powder (anhydrous zinc sulphate). If this is heated very strongly white fumes will be given off and zinc oxide will remain. Zinc oxide is yellow when hot and white when cold.

**Action of Ammonia.** Add dilute ammonia, drop by drop, to

about an inch of zinc sulphate solution in a test-tube. Shake the tube. A white precipitate of zinc hydroxide will be obtained. If more ammonia is added, the precipitate will dissolve.

**Action of Washing-soda.** Add some sodium carbonate solution to a little zinc sulphate solution. A white precipitate of zinc carbonate will be formed. Filter the precipitate. Tear off the bottom half inch of the filter-paper containing the precipitate, open out the paper, and heat it in a metal screw-cap. Zinc oxide will be produced.

**A Chemical Test for Zinc.** Drop on to a piece of filter-paper one or two drops of zinc sulphate solution and then one or two drops of cobalt chloride solution. Dry the paper by holding it over a flame and then set fire to it over a saucer. The ash which is formed will be green in colour.

## CHAPTER V

### *Experiments with Organic Substances*

THE word 'organic' was originally used in Chemistry to describe those substances which are made in the living bodies of plants and animals. Thus sugar is obtained from the sugar-cane or sugar-beet, starch from potatoes, and glue from the bones of animals. It was considered impossible to make such substances without the aid of a living organism. Chemicals like salt and sulphur, which come from mineral sources, were distinguished by calling them 'inorganic.'

Nowadays the distinction between organic and inorganic substances is made rather differently, because it has been discovered how to make most of the so-called organic substances in a laboratory without the help of living organisms at all. Chemists can make sugar, for example, which is just as sweet as ordinary sugar and quite indistinguishable from it. To-day we define Organic Chemistry as *the study of the compounds formed by the element carbon*. Strictly speaking, any substance which contains carbon is an organic compound, although a few carbon-containing substances, such as carbon dioxide and carbonates, are more conveniently studied with inorganic compounds.

It is more convenient, for several reasons, to study the compounds of carbon separately from those formed by other elements. Organic compounds possess certain characteristics which set them apart from other substances. Thus:

(i) They are usually composed of much bigger and more complicated molecules—*e.g.*, sugar has the chemical formula  $C_{12}H_{22}O_{11}$ .

(ii) They are much more numerous. More than 300,000 organic substances are known as compared with about 30,000 inorganic ones.

(iii) They are made up of very few elements, chiefly carbon, hydrogen, oxygen, and nitrogen.

(iv) When heated in air they mostly burn or decompose, often leaving a black mass of carbon.

Many organic compounds are used in everyday life, but not all of them are suitable to use in performing experiments at home. Some of them, like petrol and benzene, are highly inflammable and are too dangerous for any but expert chemists to handle. However, there are a number of organic substances which are easy to obtain, safe to use, and provide some interesting experiments.

*Citric Acid*

*Chemical Formula:*  $C_6H_8O_7$ .

Citric acid consists of white crystals, which are readily soluble in water. Like most organic acids it is a very weak acid, with little corrosive action. The sour taste of lemons, grape-fruit, and other citrous fruits is due to the citric acid which they contain. It is also present in gooseberries and raspberries. Citric acid is one of the ingredients in artificial lemonade powder. It is also often contained in health salts; it acts with sodium bicarbonate in the mixture to produce the 'fizz' when the mixture is added to water.

**Making Citric Acid Crystals from Lemon-juice.** Squeeze a lemon with the help of a lemon-squeezer and transfer the juice to a beaker. Add an equal amount of water and boil the liquid gently over a gauze and tripod for quarter of an hour. Filter the liquid while still warm into an evaporating-dish. The filtrate will be a solution of citric acid. Evaporate the solution on the gauze and tripod until only about one-third of it remains. Then put it on one side to cool and crystallize.

The crystals of citric acid obtained in this way are not very pure. They are usually coloured brown. To obtain purer crystals, dissolve the impure substance in a little water and boil the solution with powdered charcoal (preferably 'decolorizing' charcoal) for about ten minutes. Then filter the liquid and leave it in a warm place to evaporate and crystallize.

**Action of Heat.** Put a saltspoonful of citric acid crystals into an old teaspoon. Hold the end of the spoon in a paper holder and heat the substance over a small flame. The crystals will first melt and then give off a vapour which sets on fire and burns with a yellow flame. Remaining on the spoon after the action will be a black deposit of carbon, which shows that citric acid is an organic substance. The carbon can be burned off the spoon by continuing the heating.

**Obtaining Hydrogen from Citric Acid.** Put two saltspoonfuls of citric acid crystals and an equal amount of iron filings into a test-tube. Add a few drops of water and warm the tube. When the effervescence becomes fairly brisk remove the tube from the flame. Test for hydrogen by putting your thumb over the end of the tube, counting five, and then applying a lighted taper or spill to the end of the tube.

Instead of iron filings some small pieces of zinc can be used. In either case the giving off of the hydrogen is greatly promoted by adding a couple of drops of copper sulphate solution to the tube.

**Making Sodium Citrate Crystals.** Warm about an inch of citric acid crystals in a test-tube with an inch of water. When the



crystals have dissolved put the hot solution into an evaporating-dish and add a little powdered washing-soda to the dish. There will be effervescence due to the giving off of carbon dioxide. Continue adding powdered washing-soda in small amounts until effervescence ceases, showing that the acid has been used up. Evaporate the remaining solution on a gauze and tripod until about one-third of the liquid remains. When the solution is left to cool white crystals of sodium citrate will be obtained.

**An Exception to the Rule.** It is a general rule that the solubility of solid substances in water increases with rise of temperature. An exception to this rule is calcium citrate, which is less soluble in hot water than in cold water. This can be shown as follows.

Put two saltspoonfuls of chalk into a test-tube and add one or two drops of a fairly strong solution of citric acid. Carbon dioxide will be given off. When the action stops add another drop or two of the acid solution until the chalk has just completely dissolved. The clear liquid will now be a solution of calcium citrate.

Hold the tube in a paper holder and warm the solution over a small flame. A white precipitate of calcium citrate will form in the liquid, because of the smaller solubility of this substance at higher temperatures.

### Glucose

*Common Name:* grape-sugar. *Chemical Formula:*  $C_6H_{12}O_6$ .

Glucose is called grape-sugar because of its occurrence in grapes. It is also present in table syrup, black treacle, and ripe apples. Commercially, glucose is a constituent of the proprietary article Glucodin, and is widely used as a cheap sweetening material for confectionery and sweets. The sweets called barley-sugar are made largely of glucose. Glucose is only about half as sweet as ordinary sugar but is more easily digested. It is manufactured by boiling starch with dilute sulphuric acid (see p. 111).

Glucose belongs to a class of organic substances called 'carbohydrates.' These are substances made up of carbon, hydrogen, and oxygen, the hydrogen and oxygen being in the same proportion as in water.

**Action of Heat.** For this experiment use a small piece of barley-sugar or a little Glucodin. Heat the glucose on a tin-lid held in a pair of pliers or pincers. The substance will melt and turn first brown and then black, a smell of burnt sugar being given off. The final black residue of carbon is called sugar charcoal. It is a very pure form of carbon.

**Distinguishing between Glucose and Ordinary Sugar.** A solution of glucose when warmed with copper hydroxide causes a

yellow precipitate of cuprous oxide to be formed, the colour of the precipitate gradually turning to red. This experiment is described at p. 73. A solution of ordinary sugar does not answer to this test.

**Testing for Glucose in Apples and Sweets.** Cut three or four pieces of apple about the size of a pea and put them into a test-tube with a teaspoonful of washing-soda crystals. Add about an inch of water. Hold the tube in a paper holder and heat it over a small flame. When the liquid begins to boil continue the heating for three or four minutes. A reddish brown solution will gradually form in the tube and the colour will gradually darken until it is almost black. At the same time a faint smell of burnt sugar will be given off. This test also is not given by ordinary sugar.

In the same way you can test for glucose in barley-sugar and other kinds of sweets.

### *Glycerine*

*Chemical Name:* glycerol. *Chemical Formula:*  $C_3H_8O_3$ .

Pure glycerine is a colourless syrupy liquid which absorbs moisture very readily. It has a sweet taste and no smell and has no action on litmus paper. Glycerine is obtained as a by-product in the manufacture of soap (see p. 109). It is used medicinally and in the manufacture of explosives and shaving-cream.

**A Test for Glycerine.** Heat a few drops of glycerine in a dry test-tube with a little powdered sodium bisulphate. A vapour called acrolein is given off, with a penetrating smell of rancid fat.

**A Curious Colour Change.** Dissolve a saltspoonful of borax in half a test-tubeful of water and add one or two drops of phenolphthalein solution. The liquid will turn a rose-red colour. Now make a weak solution of glycerine by dissolving one drop of glycerine in an inch of water in another test-tube. Add the glycerine solution, drop by drop, to the borax solution until the red colour disappears. If now the tube is warmed the red colour will reappear, only to vanish once more when the tube is cooled. This can be repeated as often as desired.

A similar effect is obtained by using sugar solution in place of glycerine (see p. 112).

**Oxidation of Glycerine.** Add a few drops of hydrogen peroxide and a small crystal of ferrous sulphate to half an inch of glycerine in a test-tube. Hold the tube in a paper holder and warm the mixture over a small flame. A vigorous action will take place, the glycerine being oxidized to a substance called glyceraldehyde. To test the product add it to a blue precipitate of copper hydroxide obtained with copper sulphate solution and sodium hydroxide solution. When

the tube is warmed a yellow precipitate (which turns red) of cuprous oxide will be formed.

**Action on Sugar.** Put into a dry test-tube half an inch of glycerine and an equal amount of sugar. Heat the tube over a small flame. A black mass of carbon will be formed in the tube.

**Action on Cobalt Chloride Solution.** This is another interesting colour change. Dissolve a saltspoonful of cobalt chloride in an inch of water in a test-tube and add half an inch of glycerine. When the tube is warmed the red colour of the liquid will change to a beautiful violet-blue colour. The red colour will return when the tube is cooled.

### *Milk*

Besides water milk contains fat, milk-sugar (or lactose), and a chemical called casein. When milk is allowed to stand the fat rises to the surface as cream. In the manufacture of butter and cheese the cream is separated. The remaining watery liquid, known as skimmed milk, is a solution of milk-sugar and casein. For many years little use could be found for skimmed milk beyond evaporating off the water and selling the resulting powder as 'dried milk.' Nowadays skimmed milk is an important material, because the casein which it contains is used for making one of the chief kinds of plastics, the casein plastics. These are described at p. 208.

**Obtaining Casein from Milk.** This is done by causing milk to curdle by means of an acid. You can use skimmed milk or dried milk which has been reconverted to milk by mixing with warm water (see the instructions on the tin). If ordinary milk is used, allow it to stand for a time and pour off the top layer of cream.

Warm half a beakerful of the milk, but stop heating before the beaker becomes too hot to hold in the hand. Pour into the beaker, while stirring the milk with a glass rod, a test-tubeful of vinegar. The milk will immediately curdle. Remove the curd with a spoon on to a newspaper and squeeze out the moisture by folding the paper and pressing. The spongy mass left is casein.

Milk also curdles when it turns sour. This action is caused by germs, or bacteria. These change the milk-sugar into an acid called lactic acid, which, like vinegar, precipitates the casein as a curd. Lactic acid has the chemical formula  $C_3H_5O_3$ . When it is pure it is a white crystalline substance. It can be prepared from sour milk, and its properties investigated, as now described.

**Making Lactic Acid from Milk.** Leave a cupful of milk on a shelf for a few days until it has gone sour. Pour off the watery liquid, leaving as much as possible of the white curd behind. Filter the

liquid and boil it in a beaker for a few minutes. This will help to precipitate any finely suspended matter. Allow the liquid to cool and again filter it. The filtrate will now be an almost colourless solution of lactic acid. Test it with blue litmus paper.

Use half of the solution to do the tests described below and the other half to obtain crystals of lactic acid. The crystals are obtained by boiling the solution in an evaporating-dish on a gauze and tripod until the volume of the solution has been reduced to about one-quarter. The evaporation is completed by leaving the dish in a warm place, such as the bottom of the airing-cupboard.

**Tests on Lactic Acid Solution.** (i) Add a little of the solution to some chalk or baking-soda in a test-tube. Note the effervescence due to the giving off of carbon dioxide. Test for the latter with lime-water.

(ii) Warm a little of the solution with a few iron filings. Effervescence will occur again, this time due to the giving off of hydrogen. The action is improved by the addition of a couple of drops of copper sulphate solution, but it is difficult to obtain sufficient hydrogen to test by explosion with a lighted spill.

(iii) Boil about an inch of the solution with two or three drops of dilute sulphuric acid for a few minutes. Allow the liquid to cool and then add it to a copper hydroxide precipitate obtained from copper sulphate and sodium hydroxide (see p. 73). When the tube is warmed a yellow precipitate (which turns red) of cuprous oxide will be formed.

### *Naphthalene* (Moth-balls)

**Chemical Formula:**  $C_{10}H_8$ .

Naphthalene is a white substance, with a greasy feel and a peculiar penetrating smell. It belongs to a class of organic substances called 'hydrocarbons.' These are substances composed of hydrogen and carbon only. Most hydrocarbons (e.g., petrol and benzene) are dangerously inflammable, and should not be used for experiments at home. Naphthalene, however, is quite safe to use for the experiments described here.

Naphthalene is obtained as a by-product in the manufacture of coal-gas. Its chief uses are for making dyes, protecting clothes from moths, and getting rid of insect pests in soil. It is insoluble in water but dissolves in methylated spirit.

**Evaporating Moth-balls.** It is most unusual for a solid substance to evaporate away when left out in the air. This, however, happens with naphthalene. Leave one or two moth-balls on a saucer outside in the open air. If you examine them a few days later you will find

that they have become a lot smaller, due to evaporation. In about a week they will have disappeared completely.

**Burning of Moth-balls.** Like all hydrocarbons naphthalene burns readily. Crush a moth-ball and put a little of the powder into a metal screw-cap. Hold the latter in a pair of pliers or pincers and heat it over a small flame. The white powder will melt and then set on fire, burning with a very smoky flame owing to the high percentage of carbon contained in naphthalene (about 94 per cent of the substance consists of carbon).

**Obtaining Naphthalene Crystals from Moth-balls.** Put four or five moth-balls into a jam-jar and place a funnel in the top of the jar. Stand the jar in a saucepan containing some water (about

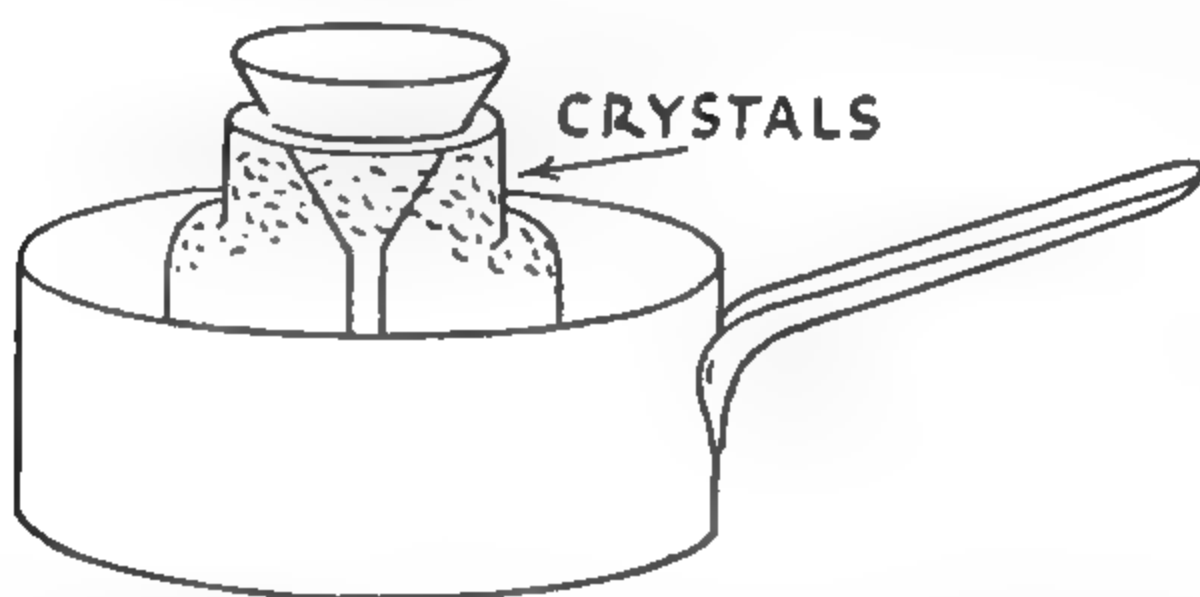


FIG. 31. METHOD OF OBTAINING CRYSTALS FROM MOTH-BALLS

an inch deep). Heat the water until it just begins to boil and then remove the saucepan from the flame. In a few minutes beautiful starry crystals will be deposited on the sides of the jar and funnel. If you remove the funnel and blow it gently, the crystals will float off into the air and glisten brightly as they slowly fall. Instead of a funnel you can use a glass plate over the jar.

In this experiment the moth-balls do not melt but change straight into vapour which condenses again on the cooler part of the jar and funnel. This change is called sublimation. It is similar to the subliming of ammonium chloride (p. 59).

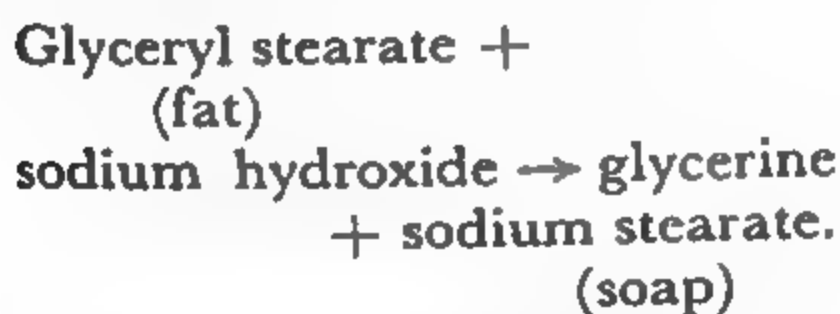
On a hot summer day moth-balls can be made to sublime merely by leaving them in a jam-jar on a window-sill where sunlight falls on the jar. Starry crystals again are formed.

Another method of making naphthalene crystals, but of a different shape, is to dissolve about two saltspoonfuls of the powdered substance in half a test-tubeful of methylated spirit by shaking (do not warm methylated spirit). Leave the solution in an evaporating-dish on a shelf to evaporate. Naphthalene crystals will be obtained in the form of pearly plates.



*Soap*

At one time soap was manufactured almost entirely from beef- and mutton-fat, but it is now made chiefly from vegetable oils (olive-oil, palm-oil, coconut-oil, etc.). These are compounds of glycerine with three organic acids, stearic acid, palmitic acid, and oleic acid. When the fat or oil is boiled with sodium hydroxide solution it splits up into its separate parts: glycerine and the three acids. The latter combine with the alkali to form soap, which is thus, from the chemical point of view, a mixture of sodium stearate, sodium palmitate, and sodium oleate. If we take stearic acid to represent the three acids, we can write the chemical action as follows:



When the boiling is complete the soap is precipitated and made to float on the surface by adding salt. The soap is then separated from the underlying liquid and allowed to set. After it has dried it is cut to the required size, stamped, and packed by machinery.

**Making Soap.** This preparation can be carried out with beef-fat, mutton-fat, lard, or olive-oil.

Put an egg-cupful of beef-dripping (which must be free from salt) or olive-oil into a beaker with about three times as much dilute sodium hydroxide solution. Add three or four small pieces of broken tile or flower-pot to ensure steady boiling and to prevent the beaker from 'bumping.' Cover the beaker with a small saucer and pour some cold water into the saucer (Fig. 32). The purpose of the saucer is to condense the steam given off in the boiling and prevent the liquid from drying up. Warm the beaker very gently at first, moving the flame about. When boiling begins continue the heating with a *small* flame, the tip of which just touches the tripod. Keep the contents of the beaker boiling for about half an hour. Then turn out the flame and allow the beaker to cool in a basin of cold water.

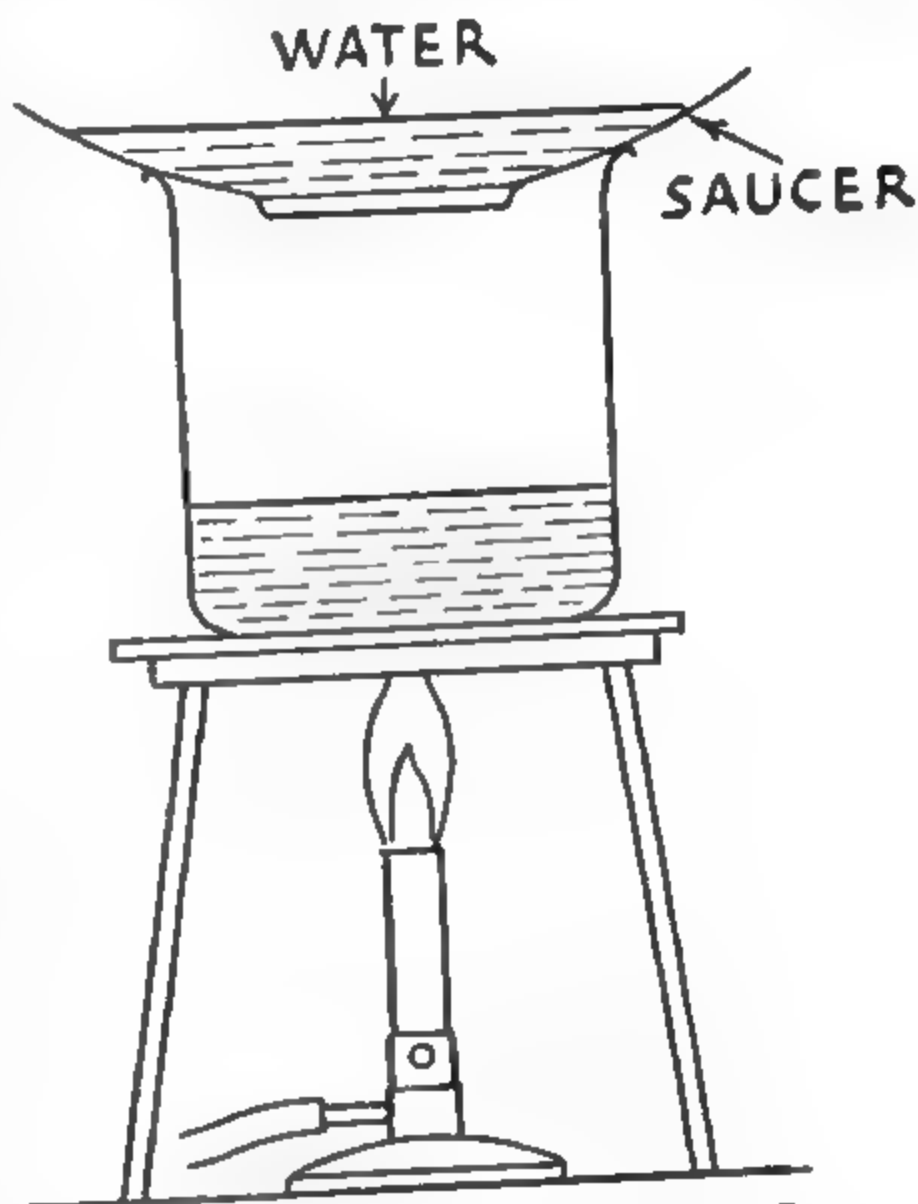


FIG. 32. METHOD OF MAKING SOAP



When the beaker is quite cold skim off any fat, or pour off any oil, which remains on the surface of the liquid. Add two teaspoonfuls of salt to the beaker and dissolve the salt in the liquid by stirring. A white jelly-like precipitate will separate out. This is soap. Run off the liquid from the beaker, keeping back the soap by means of a spoon. Swill the soap in the beaker with two or three lots of cold water to free it from alkali and salt, pouring away the liquid after each washing.

Test the soap which you have prepared by rubbing a little between the fingers. Note the soapy feel. Put a small piece of the soap into a test-tube with some warm water and shake the tube. An abundant lather will be produced.

**Tests on Household Soap.** (i) Dissolve a small piece of household soap in half a test-tubeful of warm water. Test the solution with red litmus paper. The paper should not change. Add one or two drops of phenolphthalein solution. The liquid will turn pink. A solution of good-quality soap is a very weak alkali and, although it will affect phenolphthalein, it is usually too feeble to change litmus.

(ii) Dissolve a piece of soap about the size of a pea in half a test-tubeful of warm water. Cool the tube and add a teaspoonful of salt. When the tube is shaken the soap will separate out as a white precipitate on top of the water, because it is insoluble in salt-water. This explains why it is very difficult to obtain a lather when you wash your hands in sea-water with soap.

(iii) Add a few drops of lime-water to a solution of soap and shake the tube. A precipitate of calcium stearate will form as a scum on the surface of the water. This precipitate is important in connexion with hard water (p. 128).

**Making Inflammable Soap.** Inflammable soap can be made from ordinary household soap and methylated spirit.

Put two or three small pieces of soap into a test-tube and add an inch of methylated spirit. Hold the test-tube in a pan of hot (nearly boiling) water for a minute or two and gently shake the tube. The methylated spirit will dissolve some of the soap. Pour the liquid from the tube into an egg-cup, where it will immediately solidify and form a small cake of soap. Remove the cake with a penknife on to a tin-lid and apply a light to it. It will burn for quite a long time.

### *Starch*

*Chemical Formula:*  $(C_6H_{10}O_5)_n$ .

The exact chemical formula of starch is not known. The substance, like glucose, is a carbohydrate and contains carbon, hydrogen, and oxygen in the proportion  $C_6H_{10}O_5$ , but the complete molecule is much larger than this. The formula is usually written as shown

above,  $n$  being a large number (possibly forty or fifty). Starch is present in nearly all plants; potatoes, barley, wheat, and rice are used as commercial sources. It is used for stiffening linen in laundries and for making adhesive pastes and glucose.

**Action of Heat.** Heat a little starch on a tin-lid. Decomposition will take place and inflammable gases, which smell like burning leather, will be given off. A black residue of carbon will remain on the lid.

**Action with Water.** Shake a small pinch of powdered starch with half a test-tubeful of water. The starch will not dissolve. Test the liquid by adding one drop of iodine solution. No reaction will be given.

Now boil a small pinch of starch with half a test-tubeful of water for a few seconds. The starch will dissolve. Cool the tube under the tap and add one drop of iodine solution. A deep blue-black liquid will be formed (see p. 42).

**Testing Adhesive Paste for Starch.** Shake a drop of the paste with a little water in a test-tube and add a drop of iodine solution. If the paste contains starch the contents of the tube will turn blue-black. If a red colour is obtained the paste contains a chemical called dextrin, which is made from starch.

**Making Glucose from Starch.** Boil a saltspoonful of starch with half a test-tubeful of dilute sulphuric acid or sodium bisulphate solution for two minutes. Then pour off a few drops of the liquid into another test-tube, cool it under the tap, and test it by adding a drop of iodine solution. The liquid will turn red. The starch has been changed into dextrin, a substance which, like starch, is given the formula  $(C_6H_{10}O_5)_n$ . In this case, however,  $n$  is supposed to be a much smaller number than for starch.

Continue boiling the remainder of the liquid for another three minutes. This will convert the dextrin into glucose. To show that glucose has been formed, cool the liquid and just neutralize it in an egg-cup with dilute sodium carbonate or sodium hydroxide solution (test with litmus paper). Add about an inch of the neutralized solution to a precipitate of copper hydroxide made from solutions of copper sulphate and sodium hydroxide. If the tube is warmed a yellow precipitate, which turns red, of cuprous oxide will be obtained.

### Sugar

**Chemical Name:** sucrose. **Chemical Formula:**  $C_{12}H_{22}O_{11}$ .

Like glucose and starch sugar is a carbohydrate. It is manufactured from the sugar-cane or sugar-beet.

**Action of Heat.** Heat a little sugar on a tin-lid. The substance will melt and form a liquid, which soon will turn brown. If it is

cooled at this stage the brown solid obtained is called caramel. When heated more strongly the sugar decomposes giving off inflammable vapours and leaving a black mass of sugar charcoal on the lid.

**Action of Sodium Bisulphate.** Mix together a saltspoonful of sugar and a saltspoonful of powdered sodium bisulphate. Heat the mixture in a dry test-tube. The contents of the tube will swell up forming a black puffy mass of carbon.

**Making Glucose from Sugar.** Boil a saltspoonful of sugar in a test-tube with an inch of dilute sulphuric acid or sodium bisulphate solution. Keep the liquid boiling for two or three minutes and then cool the tube under the tap. To show that the solution now contains

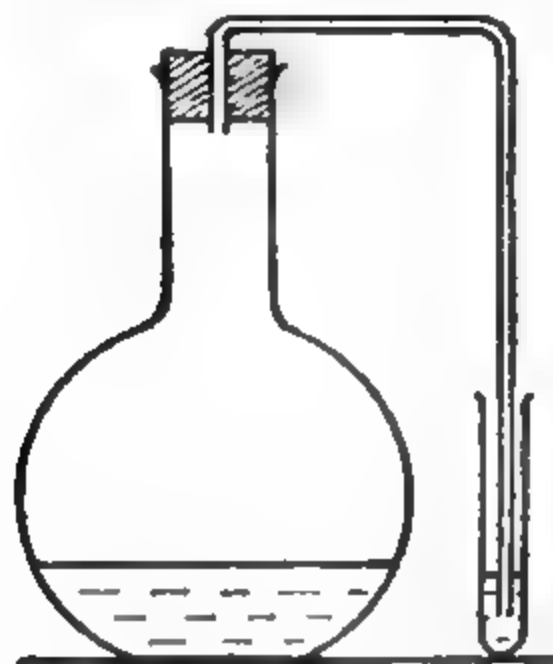


FIG. 33. THE FERMENTATION OF SUGAR BY YEAST

glucose, first neutralize the remaining acid with sodium carbonate or dilute sodium hydroxide solution (test with litmus paper). Then apply the copper hydroxide test as described at p. 73.

**A Colour Reaction.** Sugar has a similar action to glycerine on borax and phenolphthalein (p. 105), but different strengths of solutions are required.

Dissolve half a saltspoonful of borax in a test-tube nearly full of water and add one or two drops of phenolphthalein to obtain a rose-red liquid. Now add solid sugar, a little at a time, and shake the tube. The colour will disappear. Heat the tube; the colour will re-appear, only to vanish again when the tube is cooled under the tap.

**Fermenting Sugar with Yeast.** Fermentation is a chemical action caused by lowly forms of life, such as bacteria and moulds. We have already seen an example of this in the turning sour of milk (p. 106). Baker's yeast is a simple form of plant life which, under suitable conditions, is able to turn sugar (and starch) into alcohol and carbon dioxide. In bread-making it is the carbon dioxide gas which puffs up the dough and makes the bread light.

Dissolve a teaspoonful of sugar in a cupful of water and put the solution into a flask which is fitted with a delivery-tube dipping into lime-water (Fig. 33). Add a teaspoonful of yeast (a baker will usually oblige) and leave the apparatus in a warm place, such as a shelf of the airing-cupboard. In an hour or two the contents of the flask will begin to froth and the lime-water will turn milky, showing that carbon dioxide is being given off.

If the flask is left for two or three days and the contents are then filtered, alcohol can be obtained from the filtrate by distillation. The reader should be warned, however, that it is illegal to distil

alcohol, and an offender is liable to a long term of imprisonment, besides having his apparatus confiscated! When the distillation is done in a laboratory the first few drops of the liquid obtained by distillation burn with a blue flame, which is characteristic of alcohol.

### *Tannic Acid* (Cold Tea)

This acid is present in 'stewed' tea and in oak-galls. The chemical formula is complicated and uncertain. The experiments here described can be performed with the liquid left in the tea-pot at the end of a meal. Alternatively, you can make a solution of tannic acid by cutting an oak-gall into pieces and boiling the pieces with water. The acid can also be bought at a chemist's shop as a brown powder. It is sometimes used in tannic acid jelly for dressing burns, but this treatment is now out of date.

**Action of Ferrous Sulphate.** Wash a small crystal of ferrous sulphate in a test-tube with water and pour away the water. This is to remove any surface layer of ferric sulphate which would react with the tannic acid, as described in the next experiment. Dissolve the crystal in half a test-tubeful of cold water and add a few drops of cold tea. A violet-coloured liquid will be formed.

**Action of Ferric Salts.** Add a few drops of cold tea to a solution of iron alum or ferric chloride. A black precipitate of ferric tannate will be obtained. This black substance is the basis of most types of blue-black ink (see p. 76).

**Action of Dilute Sulphuric Acid.** Add a little dilute sulphuric acid or sodium bisulphate solution to half a test-tubeful of cold tea. The liquid will become cloudy, owing to the precipitation of tannic acid from the tea. If the liquid is now tested with a ferric salt solution, as in the previous experiment, no black precipitate will be formed.

**Action of Lime-water.** Add about an inch of lime-water to an equal amount of cold tea in a test-tube and boil the mixture. A reddish-brown precipitate, containing the calcium salt of tannic acid, will be produced.

### *Tartaric Acid*

*Chemical Formula:*  $C_4H_6O_6$ .

Tartaric acid is a white crystalline substance manufactured from grape-juice. It is only a very weak acid. It is commonly used as an ingredient of effervescing health salts and its salt, potassium hydrogen tartrate, is used in baking-powder under the name of 'cream of tartar.'

Tartaric acid is similar in most of its chemical actions to citric

acid (p. 103). Thus it liberates carbon dioxide gas from carbonates and bicarbonates and it gives hydrogen when warmed with iron filings or zinc.

*Vinegar*  
(Acetic Acid)

Vinegar is a weak solution (4-5 per cent.) of acetic acid. Pure acetic acid is a colourless liquid, which in cold weather solidifies to ice-like crystals called glacial acetic acid. The chemical formula of acetic acid is  $C_2H_4O_2$ . It is only a weak acid, but, like citric and tartaric acid, it yields carbon dioxide with chalk, baking-soda, etc., and hydrogen with iron filings and zinc. Acetic acid is used in the manufacture of artificial silk, 'non-flam' celluloid (p. 228), and various chemicals. By treating copper with acetic acid in the presence of air a greenish-blue pigment called verdigris (impure copper acetate) is obtained.

**Making Verdigris from Copper and Vinegar.** Put a copper coin in a saucer and pour a few drops of vinegar on to the surface of the coin. Leave the coin undisturbed for a few hours, until the liquid has evaporated. Greenish-blue particles will be left on the surface of the coin. Scrape these off on to a piece of white paper and wash the coin. If the coin is an old one black copper oxide previously on the surface will have been removed, but black copper sulphide (see p. 71) will still remain.

**Decolorizing Vinegar.** This can be done by boiling the vinegar for a time with decolorizing charcoal, which can be bought. Ordinary charcoal is not very successful. The following method works fairly well if the vinegar is first neutralized with ammonia.

Half fill an egg-cup with vinegar, and put in a piece of litmus paper. Add dilute ammonia to the egg-cup (stir the liquid) until the litmus paper just turns blue. Transfer the liquid, now a solution of ammonium acetate, to a test-tube, add a few drops of hydrogen peroxide, and boil the mixture. In a few minutes the brown colour will disappear, being destroyed by the oxygen from the hydrogen peroxide. Use the liquid left for the next experiment.

**Testing for Acetic Acid in Vinegar.** Cool the neutralized acetic acid remaining from the previous experiment under the tap. Add to it a few drops of iron alum or ferric chloride solution. The liquid will turn a bright red colour.



## CHAPTER VI

### *Miscellaneous Experiments*

#### *Some Home-made Apparatus*

CERTAIN items of apparatus which are very useful in experiments are rather expensive to buy. In the earlier part of the book substitutes which could be used in many cases were suggested. Directions are now given for making at home, at practically no cost, substitutes for a stand and clamp, mortar and pestle, and a tripod (see Plate 1). While it is not pretended that the substitutes are as efficient as the real articles, they will prove useful until the real articles can be bought. The only expense involved in making the substitutes is the buying of three or four pounds of cement from a decorator's shop, which will cost about sixpence. Plaster of Paris can be used in place of cement—except for the mortar and pestle—but is a little more expensive. The other materials can mostly be found at home.

**A Stand and 'Clamp.'** The materials required are a flat cardboard lid, a circular wood rod, cement or plaster of Paris, and some stout copper wire. The cardboard lid should be six or seven inches long and four or five inches broad. For the rod a length of dowel-rod from twelve to eighteen inches long and half an inch thick is suitable.

First make a hole through the rod about ten inches from the end which is to be the bottom of the upright. The hole can be drilled or it can be made by means of a hot nail held in a pair of pliers.

Put two cupfuls of cement or plaster of Paris into a large basin. Make it into a stiff paste by adding water to the cement or cold tea to the plaster of Paris. Cold tea is used for the plaster of Paris, because the mixture sets more slowly than with water and thus gives more time for working.

Fill the cardboard lid with the paste and press the rod into it so that it stands upright. If you have difficulty in making the rod stand upright on its own, owing to the paste being rather thin, put a book under one side of the lid, so as to tilt it, and rest the top of the rod against the wall. Leave the lid and rod undisturbed for twenty-four hours to allow the cement to set. With plaster of Paris setting will occur in about half an hour. The rod will now be firmly embedded in the lid.

Obtain about a foot of thick, bare copper wire. If necessary, this can be bought for a copper or two at an electrician's. Thread the wire through the hole in the rod and wrap about three inches at one



end round the rod. Articles like test-tubes and flasks can be supported by wrapping two or three turns of wire at the other end round them. The arrangement is shown in Fig. 34.

**A Mortar and Pestle.** These are desirable items in any chemical outfit. It is often necessary to powder chemicals which are in the form of lumps or large crystals, and this can be done most quickly and conveniently in a mortar by grinding with a pestle. A mortar

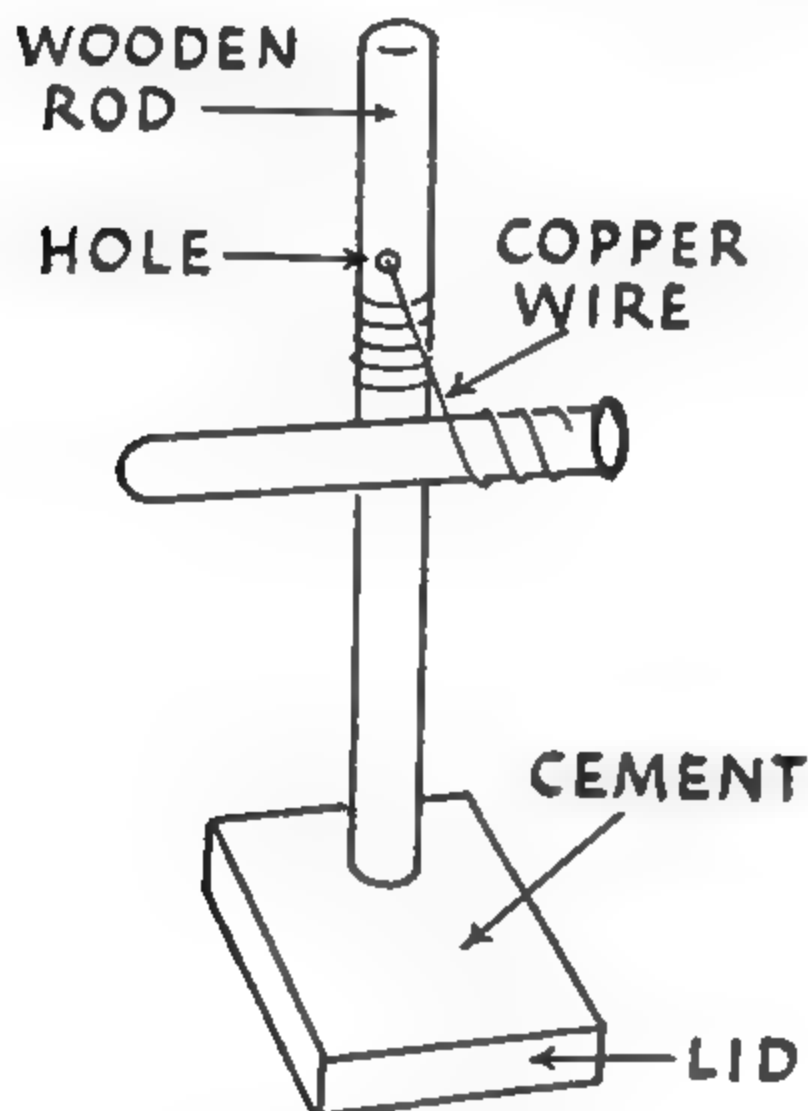


FIG. 34. A HOME-MADE STAND AND 'CLAMP'

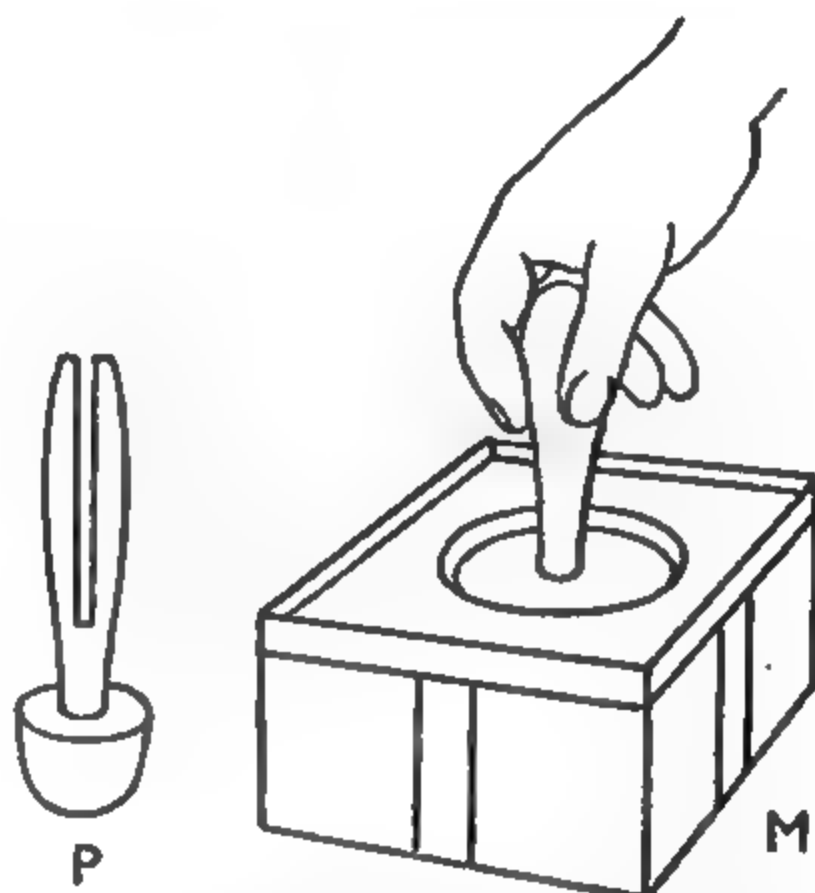


FIG. 35. METHOD OF MAKING THE HOLE FOR A MORTAR (M); A PESTLE (P)

and pestle can be made at home from a mixture of cement and sand and suitable moulds in which to shape the mixture.

Greengrocers usually sell mustard-and-cress in small boxes made of thin strips of wood. One of these boxes serves excellently as a mould for the mortar. Alternatively, a tall tobacco tin or a cardboard box measuring four or five inches square and three or four inches high can be used. An egg-cup with a curved inside makes a satisfactory mould for the pestle.

To make the mortar, line the inside of the mustard-and-cress box with brown paper so that no holes are left. Mix together in a large basin three parts of powdered cement to one part of clean sand. The quantities required will depend on the size of the box, but probably six tablespoonfuls of cement and two tablespoonfuls of sand will be sufficient. Extra hardness in the finished article can be obtained

by substituting a little fine gravel (the kind sometimes spread on roads is suitable) for some of the sand.

Add water, a little at a time, to the mixture and stir with a tablespoon until the mixture has become like a thick porridge or dough. If you add too much water accidentally, so that the mixture becomes thin, add a little more cement and stir it in. When you think the mixture has the right thickness transfer sufficient of it to fill about three-quarters of the box. Press the mixture into the corners of the box with the back of the tablespoon.

Now make a circular hole in the middle of the mixture. This can be done with a wooden stocking-mender, as illustrated in Fig. 35, or with the bottom of an evaporating-dish, a ball, or any object of suitable size and shape. Press well down into the mixture, so that the hole extends to within about an inch of the bottom of the box. A deep mortar is more satisfactory in use than a shallow one. If the mixture is of the right thickness the hole will roughly keep its shape when you remove the stocking-mender. Smooth the sides of the hole with your finger or the back of a spoon.

Leave the box on a shelf for a day or two. The cement and sand mixture will then have set, forming concrete. The mortar, however, will not yet be ready for use. Although the mixture will have set, it will not have hardened. Hardening depends upon drying, and this takes several weeks to complete. However, if the mortar is left for a fortnight in a dry place, it will be hard enough to use. Drying should be gradual, so do not try to hurry it by leaving the mortar in a warm place. Too rapid drying results in cracks appearing in the surface. Before leaving the mortar to dry strip away the wood and paper around it and smooth away any unevenness on the sides of the mortar with sandpaper.

A pestle is not actually required, because lumpy material can be powdered in a mortar quite easily with the help of a smooth stone. Since, however, the reader may prefer to do the job in a more professional manner, the making of a pestle will now be briefly described. This operation is conveniently carried out at the same time as the making of the mortar.

Obtain an egg-cup with a curved inside. Smear a little fat or margarine round the inside to prevent the cement from sticking to the sides. When the cement and sand mixture has been made fill about three-quarters of the egg-cup with it. Insert a clothes-peg (or a short length of wood rod with a few notches cut into it) head downward into the mixture and press the mixture down well. If the clothes-peg tends to fall over, your mixture is too thin, and you must make it thicker with more cement.

As in the case of the mortar, leave the egg-cup for a day or two

until the cement has set. Then run the point of a penknife round the edge of the cement and remove the pestle from the egg-cup. If you have difficulty in doing the latter, warm the egg-cup by holding it well above a flame, and try again. If the pestle is still obstinate, moisten round the edge of the cement with a few drops of vinegar, wait for five minutes, and try the penknife again. The pestle will then come out easily. After smoothing the surface of the pestle with sandpaper leave it to dry and harden for a fortnight before using it.

**A Tripod.** You can make a serviceable tripod from an ordinary can with the help of a tin-opener and a pair of old scissors. As there is some risk of cutting yourself on the jagged edges of the can,

however, the author recommends that you enlist the help of your father or an adult who is used to handling a tin-opener for the first part of the operation.

The can should measure at least four inches across the top and be at least six inches high. Most cans are not tall enough to make a tripod which

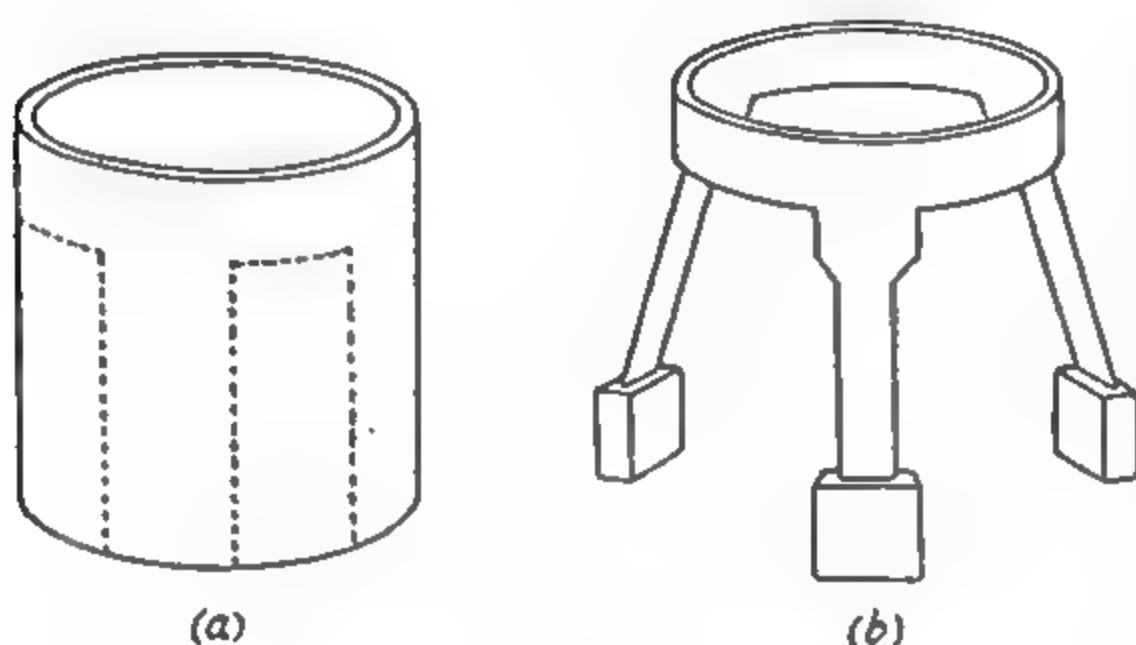


FIG. 36. METHOD OF MAKING A TRIPOD FROM A CAN

can be used with a Bunsen burner, but the height can be increased to the desired amount, as shortly described.

First cut out the top of the can completely with the tin-opener. Then, starting from the bottom of the can, make six vertical cuts at equal distances (as shown in Fig. 36 (a)) to within an inch or so from the top of the can. Next cut round and remove the base of the can. A hammer and an old screwdriver will help in getting past the seam where the sides are joined. Remove three alternate sections of the sides of the can, leaving three sections still attached to the top. Cut and shape the jagged edges of the remaining sections with the scissors as shown in Fig. 36 (b), and hammer down any sharp edges left. By bending the sections outward you will now have a small tripod.

The tripod so far constructed, however, will have two faults. It will be too low, and it will be too easily knocked over. Both these drawbacks can be overcome at the same time in the following way.

Obtain three ordinary match-boxes and cut away the cardboard at one end of each box. Fill the boxes with a thick paste made from cement and water or from plaster of Paris and cold tea. Insert the

three legs of the tripod into the mixture in the three boxes to a depth of about half an inch. In a few hours the paste will have set and the legs of the tripod will be firmly embedded. The tripod will then be ready for use (see Plate 1).

### *Match Tests for Metals*

This is a simple but effective method of obtaining certain metals from their compounds on a small scale. It can be done with a spent match, but the results are seen better if a wood spill is used. To illustrate the method the only chemicals required are washing-soda and a little copper sulphate or ferrous sulphate.

Hold a lump of washing-soda in the edge of a flame for a few seconds until the outer surface melts. Rub the lower half of the match on the melted surface, and turn the match round so that the wood becomes covered with a layer of soda. Pass the coated part of the match through the flame a few times to drive off the water of crystallization from the soda, leaving a white layer of anhydrous sodium carbonate.

Finely powder a few fragments of copper sulphate with the back of a spoon in an egg-cup. Heat the end of the prepared match for a second and dip it into the copper sulphate. Some of the chemical will stick to the end. Hold the end of the match for a few seconds in the *luminous* part of a small flame (a candle flame serves equally well). If the end of the match is now examined shiny particles of metallic copper will be seen.

If the experiment is repeated with ferrous sulphate in place of copper sulphate small fragments of iron will be left on the end of the match. It can be shown that this end of the match is attracted by a magnet. Lead can also be obtained from red lead (lead oxide) by the above method.

### *Making a Flame-test Wire*

In analysing substances chemists often use a platinum wire inserted into the end of a glass rod to carry out flame tests (p. 47) and borax bead tests (see next section). A good substitute can easily be made from the materials in a discarded electric-light bulb. If you examine the bulb you will see that the lighting filament is attached to two thicker wires which are sealed into the glass. The metal composing these wires is a nickel-iron or nickel-chromium alloy. The substitute is made by sealing one of the wires into the glass rod which is in the middle of the bulb and supports the lighting filament.

The first step is to separate the glass bulb from the brass cup. This, of course, could be done by smashing off the bulb with a hammer, but this method would not only be dangerous but would

probably break the glass rod which is required. A neater method is to cut off the glass bulb. Make a fairly deep scratch with a three-cornered file on the narrow part of the bulb near the brass cap. Starting from the file mark, lead a crack round the glass, as described at p. 32. A gentle tap will then detach the glass bulb without difficulty.

Cut off the two wires with a pair of old scissors and similarly remove the lighting filament. Cut off also the short length of glass rod with the aid of a three-cornered file as described at p. 31. To insert the metal wire, warm the cut end of the rod at first gently and then more strongly until the glass becomes cherry-red in colour and soft. Warm also one end of the wire and then press the wire into the softened glass to a distance of about quarter of an inch. Allow the glass to cool. Your platinum wire substitute will now be complete (Fig. 37).

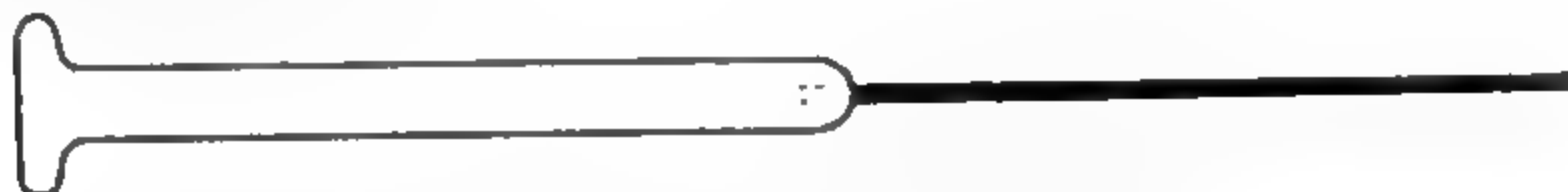


FIG. 37. A FLAME-TEST WIRE

To clean the wire between tests, leave it soaking in water for a time. Before applying a new test heat the wire strongly until it ceases to give a colour to the flame.

### *Borax Bead Tests*

Borax is a white powder and has the chemical formula  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ . The well-known borax bead test is used in chemical analysis to test for the presence of certain metals in substances.

Put a teaspoonful of borax into an egg-cup and have ready some of the following chemicals: copper sulphate, cobalt chloride, ferrous sulphate, manganese dioxide, chrome alum, and nickel sulphate. Only a few grains of each chemical in powder form are needed for the tests.

Place an evaporating-dish or white saucer beside your Bunsen burner. Heat the end of the flame-test wire in a hot flame and dip it into the borax. Some of the latter will stick to the wire. Heat the end of the wire again at the tip of a hot flame. The borax will first swell up and then form a colourless bead at the end of the wire. Make the bead a little larger by dipping the end of the wire again into the borax and heating once more.

Now pick up on the hot bead the tiniest speck that you can see of one of the chemicals. Heat the bead strongly for a minute or two and then knock it off into the evaporating-dish or saucer by quickly

tapping the wire (not the glass) on the edge of the dish or saucer. The bead will be coloured according to the metal present in the chemical. The colours obtained will be as follows:

METAL	COLOUR OF BEAD
Copper	Blue-green
Iron	Yellow-brown
Cobalt	Deep blue
Manganese	Wine-red
Chromium	Green
Nickel	Violet-brown

If a black bead results this is due to your having picked up too much chemical on the borax. In this case you should tap off the black bead, pick up more borax, and heat it with the material which remains on the wire.

To clean the wire between tests on different chemicals, heat the end of the wire and then dip it into water. If you do this two or three times you will get rid of the traces of chemical left on the wire after each test.

Although at least two of the metals in the list given are present in the metal alloy composing the wire, they will not interfere with the tests until the wire has been used many times. When they do begin to interfere—and this is usually shown by a persistent brown bead caused by nickel—the wire must be discarded.

### *A Home-made Blowpipe*

A blowpipe is used to concentrate a Bunsen flame on to a small area and thus obtain a hotter flame. With the aid of a blowpipe you can carry out experiments which are not possible with the ordinary Bunsen burner. The blowpipe illustrated in Fig. 38 is easily constructed from an oil-can spout, a length of glass tubing, and some rubber tubing.

The glass tubing and the rubber tubing should have nearly the same diameter as the wider end of the oil-can spout. If they are much narrower, cut the spout with a hacksaw at a place where it has a suitable diameter (or buy a smaller oil-can). Burn off any oil on the spout by holding it in a flame with a pair of pliers or pincers.

Use a length of glass tubing about ten inches long. Make a right-angled bend in the middle of the tubing, as described at p. 33,



and then cut off one arm one to two inches from the elbow (see p. 31). Round off the sharp edges of the glass tubing in the edge of a flame. Allow the glass to cool and connect the shorter arm to the oil-can spout with a short length of rubber tubing. Your blowpipe will now be complete.

**How to use the Blowpipe.** Before commencing an experiment with the blowpipe it is advisable to try it out with a Bunsen flame.

Close the air-hole of the burner until the flame shows only a luminous tip and then turn the gas down until the flame is about three inches high. Hold the blowpipe so that the nozzle is in the

outer edge of the flame and about half an inch above the top of the burner.

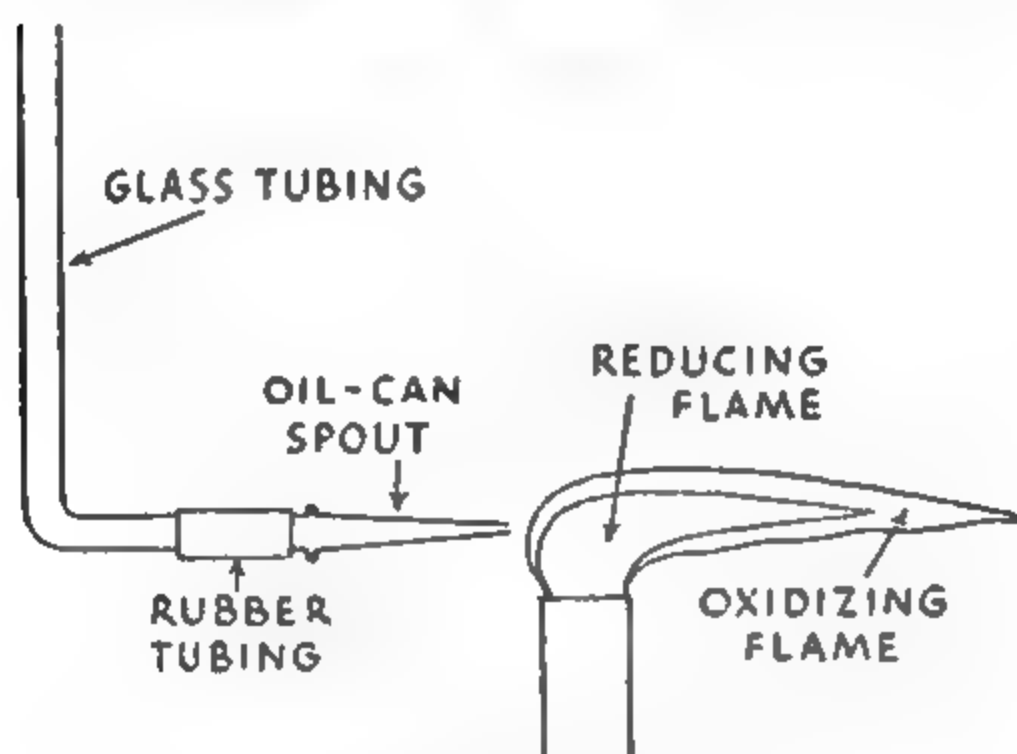


FIG. 38. METHOD OF PRODUCING A BLOWPIPE FLAME

When you blow through the blowpipe you will notice that a long, narrow flame is produced. This consists of two parts. The inner part, light blue in colour, is called the reducing flame (Fig. 38). The outer part, dark blue in colour, is the oxidizing flame. In some experi-

ments the object being heated is held in the reducing flame; in others the oxidizing flame is used.

A skilful chemist controls his breathing when he is using a blowpipe. This is done by breathing in through the nose, puffing the air into the cheeks, and breathing out through the mouth. You will find that with practice it is possible to breathe in and yet expel air from the cheeks at the same time, thus maintaining a steady flame directed on to the object which is being heated.

When you are heating substances in a metal screw-cap with a blowpipe hold the cap in a pair of pliers or pincers with one hand and grip the blowpipe with the other hand (see Plate 3). You can hold the objects in which hand you find to be convenient. Bend well down, with the elbows resting on the table or bench. If your position is uncomfortable, you will find blowpipe experiments very exhausting.

### *Some Blowpipe Experiments*

**Making Quicklime from Chalk.** On p. 82 we described the preparation of quicklime from a lump of marble or chalk. In this

experiment only the outside of the lump was decomposed. A blowpipe enables you to use powdered chalk and also to make the decomposition complete.

Half fill a small metal screw-cap with the chalk powder. Hold the cap in a pair of pincers, as illustrated in Plate 3, and heat it for five to ten minutes in the oxidizing part of the blowpipe flame. If the powder tends to blow out of the screw-cap when you start heating, cake it together by adding a drop of water. This will cure the trouble.

Notice the brilliant light given out by the substance after it has been heated for a minute or two. This is the 'limelight' (p. 82). When the heating is finished leave the screw-cap until it is quite cold. Show that the white powder which remains is quicklime by adding one or two drops of water to it. The powder will immediately 'slake.' Clouds of steam will be given off and the screw-cap will become very hot.

**Extracting Metals from their Compounds.** Several metals can be obtained from their compounds by heating the latter in the reducing part of a blowpipe flame. The action takes place better if the compound is mixed with some anhydrous sodium carbonate (p. 89) or sodium bicarbonate and if the mixture is placed in a hole in a charcoal block. A lump of charcoal about the size of a match-box is suitable, but if this is not available a metal screw-cap can be used with good results. Copper sulphate or copper oxide, red lead, and ferrous sulphate are the best chemicals to use.

If you are using charcoal, scrape a hole in it with the point of a penknife. The hole should be about half an inch across and quarter of an inch deep. Make a mixture of one part of the metal compound and two parts of anhydrous sodium carbonate or sodium bicarbonate. Put a little of the mixture into the hole in the charcoal (or into the metal screw-cap). If the piece of charcoal is too small to hold in the hand, hold it in a pair of pincers so that the heated substance is well inside the inner light-blue cone of the blowpipe flame.

Blow gently at first until the mixture shows signs of melting and then blow more strongly. The metal will be formed in a few minutes.

With red lead (lead oxide) a silvery-looking 'bead' of lead will be obtained. This can be tested when cool by inserting the point of a penknife into it, as lead is a very soft metal. The bead can also be removed on the point of the penknife and used to write on paper. Lead makes marks which are similar to pencil marks.

Copper will be left as shining particles of metal with the usual copper colour. Iron also will remain as metallic particles. If these are scraped on to a piece of paper they can be shown to be attracted by a magnet.

Other metals which can be extracted from their compounds with the aid of the blowpipe are tin, silver, and bismuth.

**Making Glass.** The only chemicals required to make glass are sodium silicate (water-glass) and chalk.

Ordinary window or bottle glass is manufactured from white sand, limestone, and sodium carbonate or sodium sulphate. These materials are mixed with a certain amount of broken glass and fused together at a high temperature. The chemical actions result in a mixture of sodium silicate and calcium silicate. These are the two compounds of which glass is chiefly composed.

Water-glass, the syrupy liquid used for preserving eggs, is a strong solution of sodium silicate. When sodium silicate is heated strongly with chalk the latter loses carbon dioxide and some of the sodium silicate is changed into calcium silicate. We thus obtain a mixture of sodium silicate and calcium silicate—that is, glass.

Put only two or three drops of the water-glass into a one-inch metal screw-cap. Hold the latter in a pair of pincers and heat the syrupy liquid strongly in the oxidizing part of the blowpipe flame. A white puffy mass of sodium silicate will form as water is driven off from the solution. Allow the metal cap to cool. Then with a pen-knife scrape out the white hard mass which remains and crush it to a powder.

Mix four parts of the powder with one part of powdered chalk and half fill the metal screw-cap with the mixture. Heat it strongly in the blowpipe flame, again using the oxidizing part of the flame. In a little while the mixture will melt and a small ball of molten glass will be formed.

**Making Special Glasses.** Additional substances are often incorporated into glass to give it special properties. Thus the addition of boron compounds produces a glass which is stronger than ordinary glass, melts more easily, and withstands sudden temperature changes without cracking. You can make this glass by heating a mixture of four parts of the powdered sodium silicate, prepared as described above, one part of chalk, and one part of borax. The resulting glass while it is hot can be readily poured out of the metal cap on to a little sand.

‘Cut glass,’ which is used for making ornaments, contains lead silicate. To make this variety, heat a mixture of five parts of powdered sodium silicate, one part of chalk, and one part of lead oxide (litharge or red lead).

Coloured glasses are obtained by adding traces of various metallic compounds to the mixture before heating. Typical compounds and the colours which they produce are the following: ferrous sulphate—greenish-yellow; manganese dioxide—wine-colour; cobalt chloride

—blue; carbon—amber; copper sulphate—greenish-blue. By means of these chemicals you can colour any of the glasses, the preparation of which has been described. You should add, however, only the tiniest speck of the chemical which you can get on to the point of a penknife.

**Repairing a Crack in a Hard-glass Tube.** If the crack is not more than about half an inch long it can be made to disappear completely with the help of the blowpipe. As hard-glass tubes are expensive, this is a useful thing to know. Unfortunately the method does not work with ordinary test-tubes. The secret of the method lies in slow warming of the tube followed by slow cooling. If the tube is heated too quickly, the crack will be widened.

First pass the end of the tube (which should be dry) several times through a luminous Bunsen flame. Then rotate the end of the tube in the luminous flame until there is a good deposit of carbon over the bottom two inches or so of the tube. Gradually turn the flame into a non-luminous one and keep the tube rotating in the upper part of the flame until the carbon round the crack has burned off. Transfer the tube to the other hand, take up your blowpipe, and direct the tip of the blowpipe flame up and down the crack. The glass will soften and run together, thus sealing the crack. Cool the tube gradually first in a non-luminous flame, then in a luminous flame, and finally by rotating it above the flame. When it is cool the tube will be as good as new.

### *Separating Two Soluble Substances by Fractional Crystallization*

When two substances are both soluble in water they can be separated, providing there is an appreciable difference in the extent to which they dissolve. This fact is often used in Chemistry to separate two soluble substances, and the process is called 'fractional crystallization.' It was by this process that Madame Curie was able to separate radium chloride from barium chloride and thus discover radium.

Alum (potash alum) and copper sulphate are suitable substances to select for illustrating the process, because the colour of the crystals shows clearly when each substance has been obtained. At 15° C. 100 grams of water dissolve 40 grams of copper sulphate but only 9.6 grams of alum, so that alum crystals are deposited first from a mixed solution of the two when the solution is allowed to crystallize.

Dissolve a level teaspoonful of alum in half a test-tubeful of warm water and about the same amount of copper sulphate in the same amount of warm water. Mix the solutions together in an evaporating dish. Cover the dish with a piece of cardboard pierced with a few holes and leave the liquid in a warm place to crystallize.

In a day or two colourless crystals of pure alum will be found in the dish. Remove these crystals and wash them with a little cold water. Continue the crystallization, and each day remove from the solution the crystals which have been deposited. The final lot of crystals obtained when the dish has become dry will consist of blue, almost pure, copper sulphate crystals. The intermediate crops of crystals will be composed partly of alum and partly of copper sulphate crystals and will show varying shades of blue.

Another pair of common chemicals which can be separated by fractional crystallization is boracic acid and salt. The solubilities of

these substances in 100 grams of water at 15° C. are 4 grams and 35 grams respectively. Since both substances form colourless or white crystals, the pure substances obtained by fractional crystallization should first be washed with a little cold water and then tested to prove their identity. This can be done by means of the flame test (p. 47), boracic acid giving a green flame and salt a golden-yellow flame.

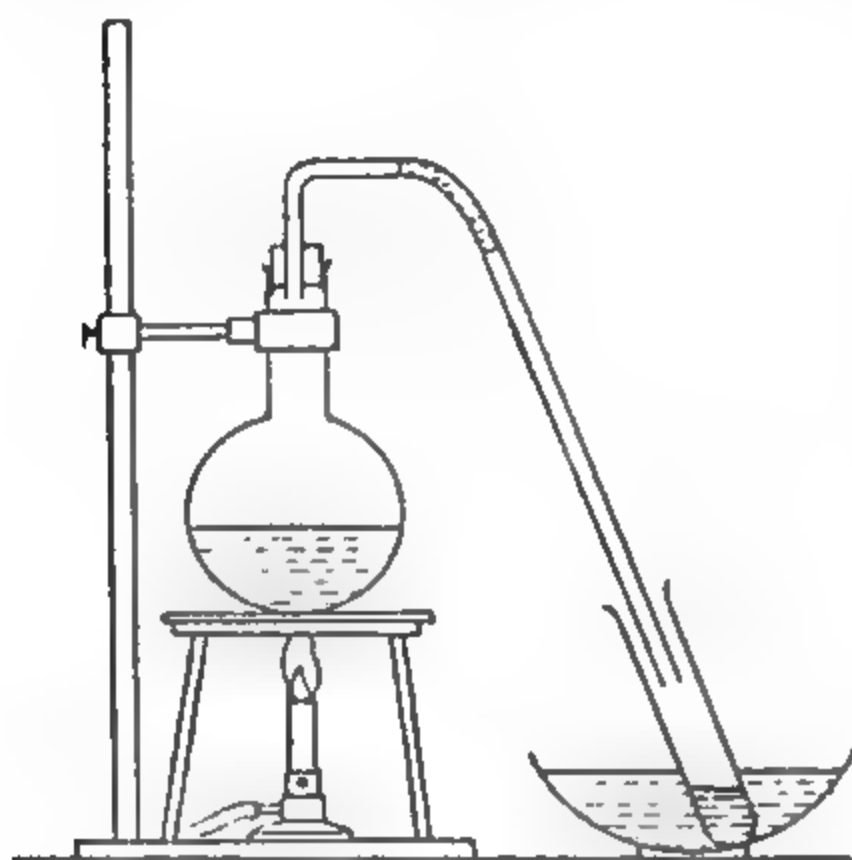


FIG. 39. APPARATUS FOR DISTILLATION

### *Distillation*

When a solid substance has been dissolved in water the substance can be recovered by simply allowing the water to evaporate from the solution. If, however, we wish to get pure water from the solution, we have to distil the solution. Distillation is a double process. It consists of turning the water into steam by heating, followed by cooling of the steam to condense it to water again. Ordinary tap-water, although pure enough for drinking, is not sufficiently pure for some purposes, owing to the dissolved salts which it contains. Thus distilled water is always used for 'topping up' motor-car batteries.

One simple method of making distilled water at home is to attach some wide rubber tubing, such as Bunsen tubing, to the spout of a kettle, in which some tap-water is then boiled. The other end of the tubing dips into a jam-jar placed in a saucepan of cold water standing on a chair. The cold water helps to condense the steam. You can also assist the condensing of the steam by wrapping some wet strips of newspaper round the rubber tubing and occasionally pouring a little cold water from a test-tube on to the paper.



A more efficient distillation apparatus is that shown in Fig. 39. The flask is clamped loosely to allow for expansion in heating. A glass tube, about 18 inches long, dips into a test-tube standing in a basin of cold water. Again condensation is improved by wrapping wet strips of newspaper round the tube. A suitable solution for distilling can be made by dissolving two teaspoonfuls of salt in a cupful of water, although the experiment is more striking if the solution is coloured with a few drops of ink.

Before commencing the heating add two or three fragments of broken flower-pot or a saltspoonful of sand to the flask. This ensures that the solution will boil evenly without 'bumping.' Heat with a small flame at the beginning to avoid cracking the flask. Collect a couple of test-tubefuls of distilled water. Put it into a bottle, cork it, and save it for the experiments on soft and hard water (p. 128).

### *Obtaining Acetic Acid from Vinegar by Fractional Distillation*

'Fractional distillation' is the name given to the process of separating two liquids from a mixture by means of distillation. It depends upon the liquids having different boiling-points. Thus if we have a mixture of two liquids A and B and if A has a lower boiling-point than B, there will be a tendency for A to distil over before B when the mixture is boiled.

Vinegar contains about 5 per cent. of acetic acid, the remaining 95 per cent. being chiefly water. Acetic acid is a colourless liquid boiling at  $118^{\circ}$  C., while water boils at  $100^{\circ}$  C. It is easier to separate two liquids by fractional distillation when there is a big difference between their boiling-points. The difference of  $18^{\circ}$  C. between the boiling-points of acetic acid and water is not large, but it is sufficient to enable us to carry out a partial separation of the acetic acid and water in vinegar.

Put about a cupful of vinegar into the flask of the apparatus shown in Fig. 39 and add two or three small pieces of broken flower-pot or a saltspoonful of sand to ensure steady boiling. Boil the vinegar. As the colourless liquid which first distils over is nearly pure water and you do not particularly need it, you can collect it in a beaker without bothering about cooling.

When the vinegar has been boiled down to about one quarter of its original volume collect the liquid which is now distilling in a cooled test-tube, as shown in Fig. 39. The colourless liquid collected will contain both acetic acid and water, but it will be a stronger solution of acetic acid than the original vinegar. A still stronger solution can be obtained by continuing the distillation and changing the test-tube when the first one has been nearly filled. It is a good idea to replace the water in the basin with a fresh lot of cold water



at the same time. On no account must the flask be heated until it becomes dry or it will probably crack.

The last test-tubeful of liquid collected from the vinegar contains about 10 per cent. of acetic acid—that is, it is about twice as strong as the original vinegar. By putting the liquid back into the flask and distilling it once more stronger solutions of acetic acid can be obtained. Instead of doing this, however, you can compare the strength of the liquid with that of the vinegar used for the experiment. This is done by comparing the amounts of washing-soda solution needed to neutralize equal amounts of the two solutions.

Dissolve two teaspoonfuls of powdered washing-soda in half a cupful of water. Fill a test-tube with the solution. Measure out half a test-tubeful of the vinegar and pour it into a beaker. Add a piece of litmus paper. Pour the washing-soda solution, a little at a time, into the vinegar and stir the liquid with a glass rod or wood spill. Continue adding the washing-soda solution until the litmus paper just turns blue. Note how much washing-soda solution has been used.

Repeat the neutralization, using this time half a test-tubeful of the final portion of acetic acid solution made by distillation. About twice as much washing-soda solution should be needed for the second neutralization.

### *Experiments on Soft and Hard Water*

Most people at some time or other have washed in hard water and found difficulty in getting the soap to lather. If you have had this experience you will probably have noticed, too, the grey-looking scum left round the basin after washing and wondered how all that 'dirt' could have come from your hands. The truth is that the scum has nothing to do with the dirt from your hands. It is merely the result of a chemical action between the soap and the chemicals which are dissolved in the hard water. Soft water is water which forms a lather easily with soap, while hard water is water which forms a scum, or precipitate, with soap.

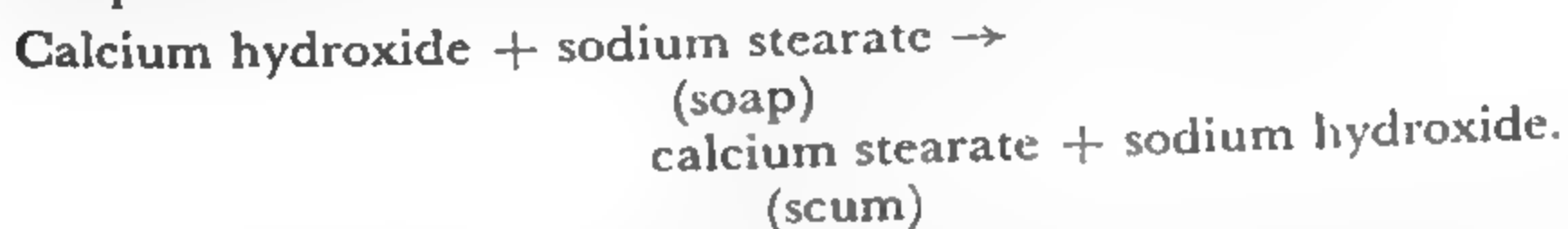
If you wish to do experiments at home on hard water, there is no need to worry because the water in your district is soft. It is a simple matter to make soft water into hard water by adding the right chemicals, as described shortly.

In doing experiments on hard water there is no necessity to wash your hands in the water every time you want to test it. A simpler method is to prepare a soap solution and use this for testing the water. A suitable soap solution can be made by cutting thin strips from a tablet of kitchen-soap and dissolving about a tablespoonful of the strips in a cupful of warm water (preferably distilled water or rain-water). The soap solution is then transferred to a clean bottle.

**How to test for Hardness in Water.** Take half a test-tubeful of distilled water or rain-water and add half an inch of your soap solution. Shake the tube vigorously. Note the pure white colour of the lather and how it consists of a mass of *bubbles*. There is no chemical action when a lather is made with soap and soft water.

Again take half a test-tubeful of distilled water or rain-water, but this time add a few drops of lime-water, which will make the water hard. Add half an inch of soap solution and shake the tube. A scum will be formed on top of the water. The scum will be rather grey in colour and consist of solid particles.

The scum is a precipitate like dozens of other precipitates which we meet in Chemistry. Most precipitates, however, are heavier than water and sink to the bottom of the tube. This one is lighter than water and floats to the surface. It is formed by an action of double decomposition between the lime-water and the soap, as follows:



Lime-water, or calcium hydroxide, is not the chemical responsible for the hardness of tap-water. For this we usually have to blame one or more of the following: calcium carbonate (chalk or limestone), magnesium carbonate, calcium sulphate, and magnesium sulphate. When these substances are present in the ground they are dissolved by water, although to dissolve the first two chemicals the water must also contain dissolved carbon dioxide gas. The insoluble carbonates are then converted into soluble bicarbonates.

When the hardness is due to the presence of calcium or magnesium bicarbonate it can be removed by boiling the water. The water is therefore described as 'temporarily hard.' When calcium or magnesium sulphate is the culprit the water cannot be softened by boiling and it is said to be 'permanently hard.'

Temporarily hard water can be made at home by passing carbon dioxide gas through lime-water for three or four minutes. The apparatus described at p. 64 (see also p. 173) is suitable for obtaining a steady stream of carbon dioxide.

**Making Temporarily Hard Water from Lime-water.** As you will require a fair amount of the hard water for testing, it is better to prepare it all at once. Half fill a boiling-tube (p. 17) or a small medicine bottle with lime-water and pass a slow stream of carbon dioxide through it with the delivery-tube at the bottom of the liquid. There will first be a precipitate of chalk, but if you continue to pass the gas through the milky liquid the precipitate will disappear

and the liquid will become quite clear. The chalk, or calcium carbonate, dissolves in the water in the presence of the extra carbon dioxide, forming a solution of calcium bicarbonate.

You should now have temporarily hard water. As the solution is rather strong, it is advisable to dilute it to about double volume by adding an equal quantity of distilled water, rain-water, or tap-water if your tap-water is fairly soft.

**Testing Temporarily Hard Water.** First prove that the water is hard, by shaking half a test-tubeful with half an inch of soap solution. A thick scum will be formed. To show that the hardness is of the temporary kind, heat a little of the water and keep it boiling for at least five minutes. The boiling is best done in a boiling-tube or beaker, as the water tends to spurt from an ordinary test-tube. When the water is boiled it will turn milky, owing to a fine precipitate of chalk. After boiling for five minutes allow the water to cool and the precipitate of chalk to settle. Then filter about half a test-tubeful of the water and test it by shaking with half an inch of soap solution. A lather will now be obtained, showing that the hardness has been destroyed by boiling the water.

If your water at home is hard you can test it as described above to find whether the hardness is temporary or permanent. If the hardness is only slight, the precipitate of chalk formed on boiling the water may be too small to see, but in cases of extreme hardness, or if water is boiled repeatedly in the same vessel, a considerable deposit of chalk is formed. The deposit is commonly called 'fur.'

**Making and testing Permanently Hard Water.** You can easily make water permanently hard with lime-water, but perhaps it is better to imitate Nature and use her chemicals. Ordinary blackboard chalk is calcium sulphate, so you can obtain permanently hard water by leaving some water for a time in contact with some pieces of blackboard chalk in a beaker or jar. A quicker method is to dissolve a saltspoonful of magnesium sulphate (Epsom salts) in a cupful of water.

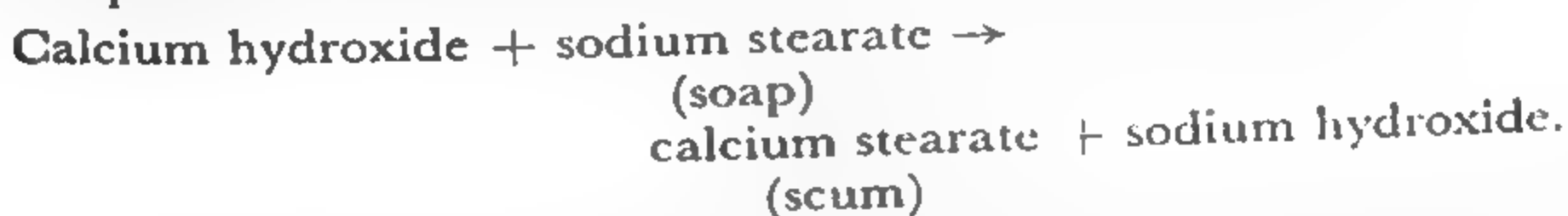
First test a little of the treated water with soap solution to make sure that it is now hard. A scum should be formed. Then boil a fresh sample of the water for a few minutes. Notice that no precipitate is formed as happened with the temporarily hard water. After boiling the water cool it and test it with soap solution. A scum will again be produced, showing that the hardness has not been removed by boiling the water.

**Softening Hard Water.** Hard water is softened by treating the water with suitable chemicals. At home the usual softening agents used are washing-soda, ammonia, and borax. Commercially, water is softened chiefly by means of slaked lime, washing-soda, and a

**How to test for Hardness in Water.** Take half a test-tubeful of distilled water or rain-water and add half an inch of your soap solution. Shake the tube vigorously. Note the pure white colour of the lather and how it consists of a mass of *bubbles*. There is no chemical action when a lather is made with soap and soft water.

Again take half a test-tubeful of distilled water or rain-water, but this time add a few drops of lime-water, which will make the water hard. Add half an inch of soap solution and shake the tube. A scum will be formed on top of the water. The scum will be rather grey in colour and consist of solid particles.

The scum is a precipitate like dozens of other precipitates which we meet in Chemistry. Most precipitates, however, are heavier than water and sink to the bottom of the tube. This one is lighter than water and floats to the surface. It is formed by an action of double decomposition between the lime-water and the soap, as follows:



Lime-water, or calcium hydroxide, is not the chemical responsible for the hardness of tap-water. For this we usually have to blame one or more of the following: calcium carbonate (chalk or limestone), magnesium carbonate, calcium sulphate, and magnesium sulphate. When these substances are present in the ground they are dissolved by water, although to dissolve the first two chemicals the water must also contain dissolved carbon dioxide gas. The insoluble carbonates are then converted into soluble bicarbonates.

When the hardness is due to the presence of calcium or magnesium bicarbonate it can be removed by boiling the water. The water is therefore described as 'temporarily hard.' When calcium or magnesium sulphate is the culprit the water cannot be softened by boiling and it is said to be 'permanently hard.'

Temporarily hard water can be made at home by passing carbon dioxide gas through lime-water for three or four minutes. The apparatus described at p. 64 (see also p. 173) is suitable for obtaining a steady stream of carbon dioxide.

**Making Temporarily Hard Water from Lime-water.** As you will require a fair amount of the hard water for testing, it is better to prepare it all at once. Half fill a boiling-tube (p. 17) or a small medicine bottle with lime-water and pass a slow stream of carbon dioxide through it with the delivery-tube at the bottom of the liquid. There will first be a precipitate of chalk, but if you continue to pass the gas through the milky liquid the precipitate will disappear

When cigarette smoke passes into the mouth each smoke particle becomes coated with a layer of moisture. This makes the particles much larger, so that they do not split up white light but merely reflect it as a whole. Therefore the smoke looks white or grey. In the same way mist, fog, and steam have a white or grey colour.

**Using a Flashlight to show the Difference in Size of Smoke Particles.** All you need for this experiment is a couple of clean, dry jam-jars, a flashlight, a piece of cardboard, and somebody to smoke a cigarette for you! The experiment should be done at night,

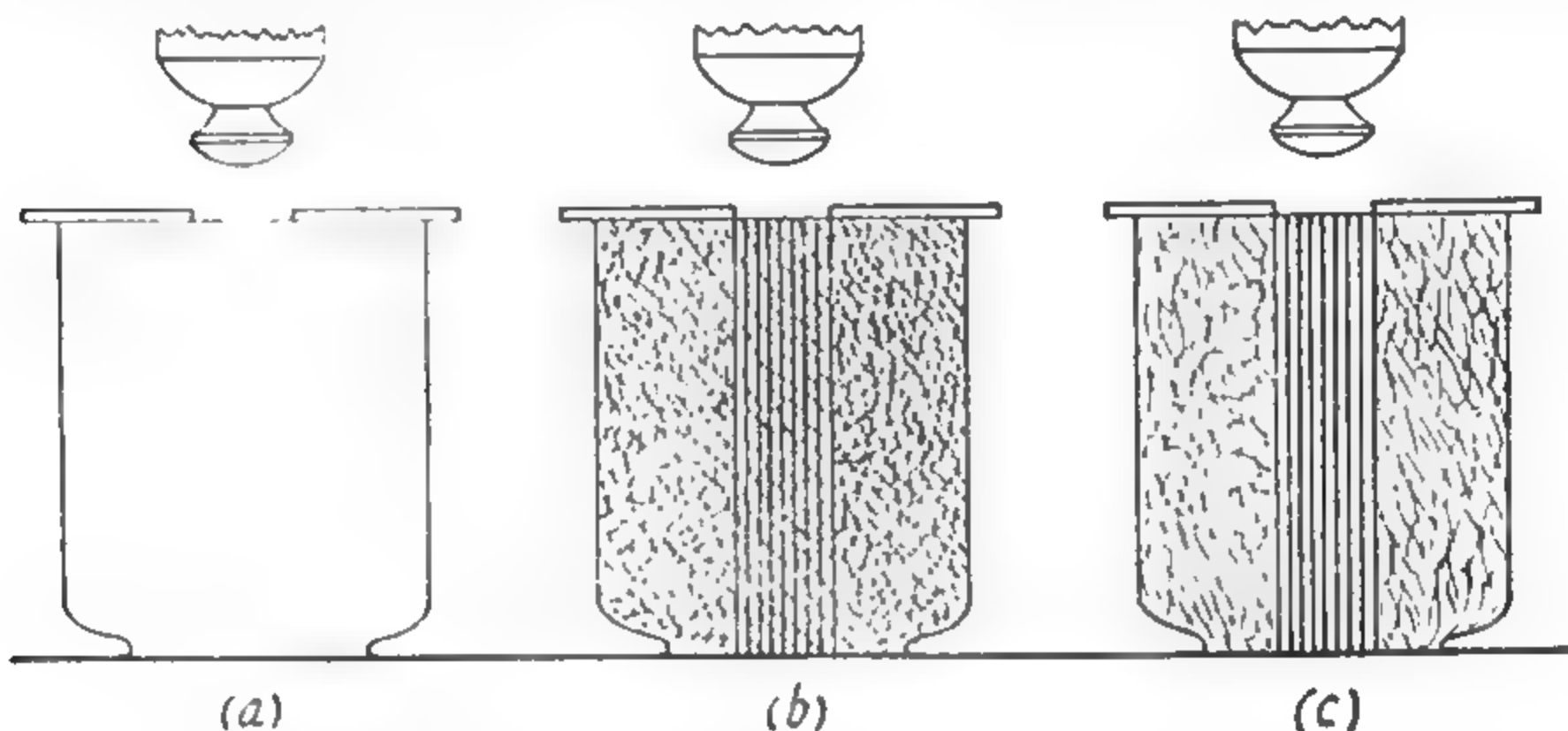


FIG. 40. SHOWING THE PATH OF LIGHT THROUGH A JAR WITH SMOKE PARTICLES

so that you can switch out the light, or you should have a dark cupboard available.

First do a preliminary experiment. Put one jar mouth downward on a dark surface (a dark book will do). Cut a hole of about one inch diameter in the cardboard and place the cardboard on top of the jar. Switch off the light. Hold the flashlight an inch or two above the cardboard (Fig. 40 (a) ) and shine the light through the jar. When you look at the jar from the side it will not be possible to see the rays of light passing through the jar.

Repeat the experiment, but this time allow a little blue cigarette smoke to pass into the jar. The path of the light rays through the jar will now be clearly shown by a white band of light which appears to be made up of a number of white lines (Fig. 40 (b) ). The effect is caused by the reflection of light by the smoke particles in the same way that sunlight in a room is made visible by dust particles in the air.

Now allow blue smoke from the lighted end of a cigarette to fill up the jar. Fill up the second jar with smoke which has been breathed out. Leave the jars standing mouth downward for about



an hour and then shine the flashlight through each of them in turn. The band of light will still be seen clearly in the first jar, but it will only be faintly visible in the second jar (Fig. 40 (c) ). The blue smoke particles, being very small and light, mostly remain floating about in the air in the jar. The larger and heavier white smoke particles settle more rapidly, and few are left floating in the jar at the end of an hour.

Very similar to smoke particles floating in air are solid particles of an insoluble substance floating in water. Thus a milky liquid is obtained when some finely powdered chalk is shaken up with water. If the liquid is allowed to stand the particles are acted upon by gravity and become deposited as a sediment. As with smoke the finer the particles the less quickly they settle. Muddy water and whitewash are good examples of a fine solid being suspended in water.

When a suspension in water is filtered the suspended particles are left on the filter-paper and the filtrate is a clear liquid. With a true solution no settling occurs, and no amount of filtering will remove the dissolved substance. This shows that the particles in a suspension are coarse as compared with those in a solution.

If the particles in a suspension are very small they cannot be seen with the naked eye. We can show that they are there, however, by means of a flashlight. With liquids there is no necessity to use jam-jars, as the effects are shown quite well by employing test-tubes.

**Showing the Presence of suspended Dust Particles in Tap-water.** Filter half a test-tubeful of tap-water. For filtering use a double filter—that is, two filter-papers folded together—as the fine particles might pass through a single filter-paper. While the water is filtering half fill another tube with tap-water. Switch off the light and shine a flashlight up through the bottom of the test-tube (see Plate 3). The path of the light through the water will be shown clearly by a white luminous cone. The cone shape is formed owing to the curved bottom of the test-tube.

Repeat the experiment with the filtered water. No cone of light will be visible, because the suspended dust particles have been filtered out of the water.

Now add a saltspoonful of sugar to the filtered water and shake the tube until the sugar has dissolved. Test this solution in the same way with your flashlight. Again no cone of light can be seen. The sugar molecules in solution are far too small to reflect the light rays and make their path visible. Shake a tiny pinch of chalk, carbon, or other insoluble substance with the solution. The cone of light will now be quite visible.

It has been said previously that if a suspension of chalk, or other insoluble substance, in water is filtered all the chalk is left on the



filter-paper. A curious method of getting the chalk to pass through the filter-paper is now described.

**Making an Insoluble Substance pass through a Filter-paper.** This experiment works well with finely powdered chalk or with mustard, but the best substance for it is rouge if you can beg a pinch from your mother or sister.

First shake only as much of the powder as you can get on the point of a penknife with half a test-tubeful of water. Allow the solid to settle, and pour off the water through a double filter-paper. The liquid obtained will be quite clear and uncoloured, because all the solid particles have been filtered out of it.

Now add another small quantity of the powder to half a test-tubeful of water, but before shaking add also one or two thin shavings of soap. After shaking the tube again filter the water through the double filter-paper previously used. The filtrate obtained this time will be coloured white, yellow, or red according to whether chalk, mustard or rouge has been used.

The filtrate which has just been obtained is a suspension and not a solution. In some way which is not fully understood the soap drags the fine particles of powder through the filter-paper. If you add to the filtrate a few drops of dilute sulphuric acid or a solution of alum or magnesium sulphate the soap will be decomposed and no longer able to keep the powder in suspension. The powder will settle and form a coloured sediment on the bottom of the tube.

**Making Emulsions.** It is often said that oil and water do not mix. If a few drops of liquid paraffin, machine-oil, or olive-oil are shaken with half a test-tubeful of water a milky-looking liquid is produced, but the mixture soon separates into two layers, with the oil floating on top. If you use filtered water (see p. 133) in this experiment you can use the flashlight test to investigate how long the tiny droplets of oil remain floating in the water. The droplets reveal themselves by giving the usual cone of white light.

The separating of an oil-water mixture into two layers can be delayed, and even prevented, by adding certain chemicals to the mixture. These chemicals are called 'emulsifying agents.' Under their influence oil and water *do* mix, and form a milky liquid which is known as an 'emulsion.' Emulsifying agents are chemicals which have an attraction for both oil and water and serve to couple the two together. Soap is quite a good emulsifying agent, and can be used to make an emulsion of oil and water.

Again add a few drops of one of the oils previously mentioned to half a test-tubeful of water (it is better if the water is slightly warm). Add also to the tube a couple of drops of soap solution made by dissolving a thin shaving of soap in a test-tubeful of warm water.

Shake the tube vigorously for a minute or two and then leave it to stand. The liquid will keep its milky appearance much longer now.

Emulsions are quite common in everyday life. One of the commonest is milk, while others are cod-liver oil emulsion, salad dressing (made from olive-oil and vinegar), and hair-creams.

Milk consists of tiny drops of oily or fatty substances floating in a watery solution. It is these tiny drops which, by reflection of white light, give milk its white or milky colour. Skimmed milk, which is left when most of the oily or fatty substances have been separated, is bluish in colour. The reason for this is that skimmed milk gets its colour from the much finer oily droplets which still remain in suspension. Like the fine particles of blue cigarette smoke these are small enough to split up white light and reflect only the blue part of the light.

**Recipes for Home-made Hair-creams.** Hair-creams are emulsions which are usually made from an oil, such as liquid paraffin, water, and an emulsifying agent. It is quite easy to make an emulsion from liquid paraffin and water by using soap as the emulsifying agent, as described previously, but it is another matter to make an emulsion which will last and which can be used as a hair-cream. We now give two ways of doing this.

(i) Obtain from a chemist's an ounce of bees-wax (preferably the white variety). This will cost about 6d. Put half an egg-cupful of the wax into a dry beaker and add two egg-cupfuls of liquid paraffin. Warm the beaker to about  $60^{\circ}\text{C}$ .—that is, until the beaker is just too hot to hold on the hand. Stir the mixture until the wax has dissolved.

In another beaker or a basin place one and a half egg-cupfuls of water which is at about the same temperature as the oil. Dissolve in the water a tiny pinch of borax picked up on the point of a penknife.

Now pour the oil in a slow stream into the water, stirring well as the oil is added. When all the oil has been added stir the mixture vigorously until it is cold (an egg-whisk makes this part of the job easier). A creamy emulsion will be formed. When it is cold transfer it to a bottle, and cork the bottle. This cream will be rather oily.

(ii) Commercial hair-creams are nowadays made with the help of more powerful emulsifying agents than bees-wax. One of these is a chemical called triethanolamine stearate, which is made by combining triethanolamine, a syrupy liquid of formula  $\text{N}(\text{C}_2\text{H}_4\text{OH})_3$ , and stearic acid, a white solid of formula  $\text{C}_{17}\text{H}_{35}\text{COOH}$ . To preserve the emulsions 'stabilizing agents' are incorporated, one of the best known being cetyl alcohol, a white solid of formula  $\text{C}_{16}\text{H}_{33}\text{OH}$ . These chemicals are not common substances and

would have to be specially ordered at the chemist's. Four ounces of each of the three will enable you to make several pints of hair-cream of excellent quality.

Put a cupful of liquid paraffin into a beaker with half an egg-cupful each of cetyl alcohol and stearic acid. Warm the beaker to about  $60^{\circ}\text{C}$ . and stir until the solids have dissolved. In a large basin put one and a half cupfuls of hot water (also at  $60^{\circ}\text{C}$ .) and dissolve in it about two thimblefuls of triethanolamine.

Pour the warm liquid paraffin mixture in a slow stream into the water, stirring as you do so. Continue stirring well for five minutes. A thick white cream will form, the thickness depending on the amount of stirring. This cream will keep indefinitely in a well-stoppered bottle.

### *A Soapy Chemical from Horse-chestnuts*

Horse-chestnuts have other uses besides enabling schoolboys to play 'conkers.' They are a source of a useful chemical called saponin. This chemical, although not the same as soap, is similar in some ways to soap. Indeed, the word 'saponin' means 'soap-like.'

**Extracting Saponin from Horse-chestnuts.** With a sharp knife cut a horse-chestnut into quarters. Remove the brown shell from the pieces and cut them into small fragments. Put these into a boiling-tube or beaker and boil them for a few minutes with about two egg-cupfuls of water. The water will dissolve the saponin out of the material. Cool the tube or beaker and filter the solution. Put a little of the solution into a clean bottle and shake the bottle. A large volume of lather will be produced. If the bottle is left undisturbed on a shelf, the lather will last for hours.

Because it forms a lather so easily saponin is sometimes put into ginger-beer and other mineral-waters to make them froth easily. Another use is in fire-extinguishers of the foam type. These have two compartments. The first one contains a solution of sodium bicarbonate mixed with saponin, and the second one a solution of an acid substance, usually aluminium sulphate. When the solutions are mixed the bubbles of carbon dioxide gas produced by the chemical action are made into a remarkably strong foam by the saponin. The foam forms a 'chemical blanket' over the burning material and, by excluding air, puts out the fire.

The use of saponin in fire-extinguishers can be illustrated by the experiment now described.

**Extinguishing a Fire with a Foam.** Put a tablespoonful of sodium bicarbonate (baking-soda) into a medicine bottle and fill the bottle one-third full with cold water. Add about half a test-tubeful of saponin solution. Have ready a test-tubeful of saturated

aluminium sulphate solution (if this is not available use a saturated solution of ordinary alum to which a little dilute sulphuric acid has been added). Soak a small wad of cotton-wool in paraffin or methylated spirit and set it on fire in an evaporating-dish, a small basin, or a metal tray. Now pour the aluminium sulphate solution into the bottle and hold the latter so that the foam which is given off falls on to the 'fire.' The burning cotton-wool will quickly be covered with the strong and lasting foam and soon extinguished.

### *Fluorescence by Flashlight*

(Some Beautiful Effects in the Dark)

In recent times a new method of lighting by electricity has come into use. The method is called 'daylight' lighting. Instead of the

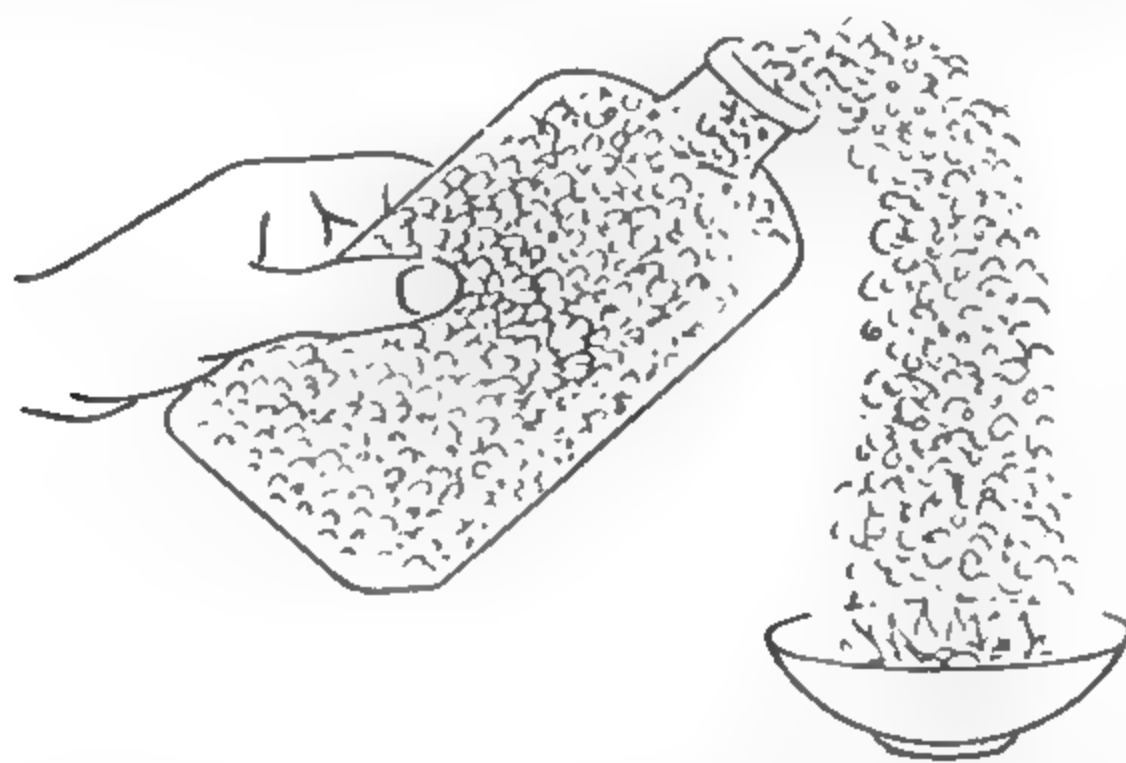


Fig. 41. A MODEL FOAM FIRE-EXTINGUISHER IN ACTION

ordinary bulb with a filament, a long tube containing an electrode at each end is employed. Air has been removed from the tube, which has a trace of mercury in it. When an electric current is passed from one electrode to the other the mercury vaporizes and gives out ultra-violet rays. These are rays which are invisible. The inside of the long tube is coated with certain chemicals which are very sensitive to ultra-violet rays. When the rays strike these chemicals they give out a brilliant bluish light. The giving out of light in this way is called 'fluorescence.'

There are several common substances which, given the right conditions, will show fluorescence with the light from an ordinary flashlight. To investigate this phenomenon you should gather together as many of the following as you can: red ink, lubricating-oil, rouge, red nail-varnish, tincture of quinine, and acriflavine solution. The last two may be found in the medicine-chest. With the exception of the lubricating-oil, only very tiny amounts of the substances are

required. To see the effects properly the experiments should be carried out at night with the light out. If possible a different test-tube should be used for each substance.

**Red Ink.** Add one drop of the ink to half a test-tubeful of water. Switch out the light. Hold a flashlight an inch or two below the tube and shine the light upward through the bottom of the tube. A brilliant cone of green light will be seen in the liquid (see Plate 3).

**Lubricating-oil.** Use about an inch of the oil in a test-tube. Often there is no result, but sometimes a dark green or blue light is obtained.

**Rouge.** Shake a few specks of the powder with half a test-tubeful of warm water and filter the liquid. A green fluorescence will be produced.

**Red Nail-varnish.** Add one drop to an inch of methylated spirit in the test-tube. The fluorescence will again be green.

**Ammoniated Tincture of Quinine.** Add two drops to a third of a test-tubeful of dilute sulphuric acid or sodium bisulphate solution. The cone of light will have a beautiful blue colour.

**Acridavine Solution.** Add one drop to half a test-tubeful of water. A green fluorescence will result.

Fluorescence is a great help to the modern chemist in analysing substances. For this purpose he makes use of the ultra-violet rays given out by a mercury-vapour lamp of the kind used for 'daylight' lighting. Many chemicals will fluoresce even though they may be present only in tiny amounts. Thus the cheaper grades of medicinal liquid paraffin sometimes contain small amounts of impurities which give a bright fluorescence with the mercury-vapour lamp. Similarly the presence of certain impurities in foods, drugs, and dyes can be instantly recognized.

The chemical called fluorescein shows the property of fluorescence to an extraordinary degree. It can be detected by its fluorescence when only one part of it has been dissolved in one hundred million parts of water. This chemical is sometimes used for tracing the course of underground streams. The sensitiveness of fluorescence tests can be shown by means of red ink in the manner now described.

**A Drop-in-a-bucket Test.** Put one drop of red ink into a bucket and fill up the bucket with water. Stir the water so that the drop of ink becomes evenly mixed. The colour of the ink will not be visible in the water. Take out half a test-tubeful of the water and shine a flashlight up through the tube in a dark room. The green fluorescence, due to the ink, will be clearly seen.

An ordinary bucket contains about three gallons of water, which is equal to about a quarter of a million drops. It is interesting to dilute the weak ink solution in the bucket still further and see how



dilute the solution can be made before its fluorescence finally disappears.

### *Simple Dyeing Experiments*

There are a number of experiments on dyeing which can be performed with materials usually found at home or which can be readily obtained. Different kinds of ink can be used. Red cochineal solution, which is used for colouring cakes, may be found in the kitchen cupboard. Logwood chips are often included in Chemistry sets. Dyes can be obtained by boiling the crushed 'leads' of coloured pencils with water. You can also do interesting experiments with vegetable dyes made from various flowers, berries, roots, and leaves. Before modern coal-tar dyes were discovered these vegetable dyes were largely employed, and a few are still in use even to-day.

Before you can dye materials successfully it is necessary for you to understand what dyes are and how they are used. It does not follow that because a substance has a bright colour it can be used as a dye. This can easily be shown by dipping a strip of cotton cloth in red ink and then holding it under the tap. The colour will be almost entirely washed out by the water. A dye is a coloured substance which can be permanently attached to the cloth. The colour is then said to be 'fast.'

It does sometimes happen that a fabric can be dyed merely by soaking it in a solution of the dye. The latter is then described as a 'direct,' or 'substantive,' dye for the fabric. Thus Congo red will dye cotton and logwood will dye wool directly. It cannot be assumed, however, that because a dye will impart a colour directly to one kind of fabric it will act similarly with a different material. Wool has such a great attraction for dyestuffs that many of them will dye this material directly, whereas very few dyes will give a colour directly to cotton.

When a dye will not give a fast colour to a fabric by direct dyeing it can often be made to give a fast colour by treating the fabric chemically before it is put into the dye. The treatment consists of depositing in the fibres of the cloth a chemical which has an attraction for the dye and makes it stick to the cloth. The process is called 'mordanting' the cloth, and the chemical deposited in the fibres is referred to as the 'mordant.'

Cotton usually has to be mordanted before it will take a dye. The kind of mordant used depends on the nature of the dye. A common method of mordanting cotton is to soak it first in alum solution and then in washing-soda or ammonia solution. This causes a precipitate of aluminium hydroxide to form in the fibres, and it is this precipitate which combines with the dye and fixes it. The hydroxides of iron



and copper can be used in the same way. Some dyes require the cotton to be first mordanted with a weak acid.

Although wool can usually be dyed directly, it is often mordanted to improve the fastness of the dye or to produce particular shades. The use of different mordants usually results in different shades being produced from the same dye. Thus an iron mordant generally gives a darker shade, while a copper mordant gives a brighter colour.

**Practical Hints.** Only two kinds of material, wool and cotton, are dealt with here. Wool can be used in the form of white flannel or white mending-wool. Cut the flannel into strips about three inches long and one inch wide or loosely knot together a few strands of wool. As new wool often contains oily impurities which interfere with dyeing, it should first be boiled in washing-soda solution for a few minutes and then rinsed out thoroughly in clean water. For dyeing cotton you can use an old cricket-shirt or cotton handkerchief cut into strips as described above.

Wool is easier to dye than cotton, as the fibres are easily penetrated by a liquid. Wool need be left only a couple of minutes in the mordanting solution or dye. Cotton fibres are tough and not easily penetrated; therefore, before you begin to dye, leave several strips of cotton soaking for a while in alum solution, and a second lot soaking in a solution of tannic acid, tartaric acid, or vinegar. Tannic acid, which is generally used to mordant cotton, can be made by boiling pieces of oak-galls with water (p. 113).

Work with one dye at a time. A fabric usually takes up colour more readily if the dye solution is hot. Also the addition of a little common salt to the dye liquor speeds up the rate of dyeing and gives a deeper colour.

As the object of the experiments is to dye the fabrics and not yourself or the table-top, you should take suitable precautions. Wear old clothes, and have a few sticks available for handling the dyed materials. Protect the top of your table or bench with old newspapers.

**Dyeing with Blue-black Ink.** Most blue-black inks contain a blue dye called indigo carmine. The following experiments work well with the usual makes of ink. Put an egg-cupful of the ink and an equal amount of water into a beaker, add a saltspoonful of common salt, and warm the beaker until you can just hold it on your hand.

(i) Leave unmordanted cotton and wool in the liquid for a few minutes. Remove the materials with a stick and hold them under the tap. The colour will be washed out of the cotton, but the wool will be dyed a light blue. This illustrates the greater attraction of wool than cotton for dyes.

(ii) Leave in the warm liquid a cotton strip which has been soaked for some time in a weak acid (tannic acid, tartaric acid or vinegar). After about five minutes remove the cloth with a stick and hold it under the tap. The cotton will now be dyed a bright blue colour which is not washed out.

(iii) Mordant a few strands of wool with aluminium hydroxide. This is done by soaking the wool first in a strong solution of alum, squeezing out the liquid, and then putting it into weak ammonia or washing-soda solution, again squeezing out the liquid. Leave the mordanted wool in the warm ink solution for a couple of minutes and then wash it under the tap. The wool will be dyed a deep purple colour.

(iv) To see the effect of using a different mordant on the wool, soak a few strands first in ferrous sulphate solution and then in weak ammonia. This produces a precipitate of iron hydroxide in the wool. This time the wool will be dyed an almost black colour by the ink.

A good method of testing the fastness of the colour in a dyed material is to leave it in water in a cup or jar for an hour or two. If the colour is perfectly fast no trace of it will be found in the water, even after several hours.

**Dyeing with Red Ink.** Not all manufacturers use the same dye in making red ink, but one dye commonly used is eosin. Most brands of red ink can be used to dye cotton and wool in the same manner as blue-black ink. Use an egg-cupful each of water and red ink, add a little salt, and have the solution boiling. The cotton should be mordanted with a weak acid and the wool with aluminium or iron hydroxide as described in the previous section.

An interesting experiment is to take samples of wool which have been dyed with red ink and put them into a weak, warm solution of blue-black ink. Various shades of purple will be produced, according to the strength of the second liquid and the time for which the wool is left immersed. This illustrates the process of 'double dyeing.'

**Dyeing with Cochineal.** Cochineal is a red dye made from the dried bodies of an insect which lives on certain kinds of cactus growing in Mexico. As cochineal is a strong dye, it is necessary to add only a few drops of the solution to half an inch of water in a beaker to obtain a suitable dyeing liquid. Add a little salt, and have the liquid boiling.

Both the cotton and wool should be mordanted. The most suitable method in both cases is to soak the cotton and wool first in alum solution and then in a solution of tartaric acid, or cream of tartar. Remember that cotton must be soaked for a longer time than wool. With cotton a pink colour will be obtained and with wool crimson.

Both cotton and wool give different shades of red when dyed with cochineal, according to the mordant used. Other mordants which can be tried are alum and ammonia, ferrous sulphate and ammonia, copper sulphate and ammonia. In the last case the ammonia should be very dilute (one part of strong ammonia to ten parts of water).

**Dyeing with Logwood.** Logwood chips are obtained from a tree which grows in South America. When the chips are boiled with water a reddish-purple liquid is obtained. This liquid is used to make certain kinds of ink and to dye silk black (with an iron mordant) for use in umbrellas. The chips should be boiled with water for about fifteen minutes and the resulting solution filtered. For dyeing have the solution boiling.

To dye cotton and wool both should be mordanted. For mordanting cotton you can use either a weak acid (tannic acid, tartaric acid or vinegar) or one of the metal hydroxides (aluminium, iron or copper), precipitated in the cotton as described previously. For wool use one of the metal hydroxides. It will be found that the use of an iron mordant gives a black colour which is quite fast.

**Other Common Dyes.** Congo red, methylene blue, methyl violet, malachite green, and rosaniline (magenta) are well-known dyestuffs which are readily obtained from chemical dealers and are simple to use. They all dye wool directly, but only Congo red is a direct dye for cotton. In the other cases the cotton must first be mordanted with a weak acid.

Congo red can be used as an indicator (p. 40), and cotton which has been dyed with Congo red turns blue when put into an acid. Methylene blue and the other dyes mentioned above are commonly used in coloured inks and pencils. Methyl violet is also used for typewriter ribbons.

**Dyeing with Vegetable Dyes.**<sup>1</sup> Some very beautiful and delicate colours can be obtained by dyeing wool and cotton with extracts from various parts of common plants, trees, and shrubs. In all cases the material should be used soon after it has been collected and not allowed to wither. The dye is extracted by boiling the material with water in a saucepan for five to ten minutes. The coloured liquid is filtered when cool. The following experiment illustrates the method of using a vegetable dye.

Boil a couple of deep red carnations with a tumblerful of water for five minutes in a small saucepan covered with a lid. Cool and filter the red solution. Meanwhile mordant strips of wool and cotton by soaking them first in alum solution and then in tartaric acid, or

<sup>1</sup> For fuller information on the use of this class of dyes see *The Use of Vegetable Dyes for Beginners*, by Violetta Thurstan (Dryad Press, Leicester, 1943).

cream of tartar (this gives a better mordant than aluminium hydroxide). Add some tartaric acid also to the dye. Boil the dye solution in a beaker and add the strips of wool and cotton. Leave the strips immersed until the beaker is cold and then remove them and wash them under the tap. The wool will be dyed a deep red and the cotton a soft pink. With an iron mordant (ferrous sulphate followed by dilute ammonia) a deeper shade of red will be obtained.

The sources of some other vegetable dyes and the colours which they produce are given below. All of them will dye wool, but only some are successful with cotton.

**FLOWERS:** barberry, chrysanthemums (yellow), daffodils, golden rod, gorse, marigolds, ragwort. These give a yellow dye. Red roses give a red dye.

**LEAVES:** birch, pear, privet, yarrow. Yellow dyes are obtained. Parsley gives a green dye.

**BERRIES:** blackberries, bluish grey; damsons, purple; elderberries, purple (black with iron mordant); juniper, brown.

**VARIOUS:** walnut shells, brown; pine cones, yellowish red; apple bark, yellow; iris roots, black.

### *A Fountain Experiment*

This experiment is commonly used to demonstrate the solubility of very soluble gases, like ammonia (p. 178), but it can also be carried out with water in the manner now described.

Fit a flask with a tightly fitting cork through which passes a length of glass tubing twelve to fifteen inches long. The experiment works better if the end of the tube inside the flask is drawn out into a jet (see p. 36). Put an egg-cupful of water into the flask. Hold the flask by means of a cloth wrapped round the neck and heat the flask over a *small* flame, moving it about well over the flame. When the water has boiled for a minute or so and steam is issuing from the tube turn the flask upside down and put the end of the tube into a basin of water (Fig. 42). Do this carefully but quickly. The water will rise rapidly up the tube and form a fountain inside the flask. The effect will be more striking if you colour the water in the basin with a drop or two of ink.

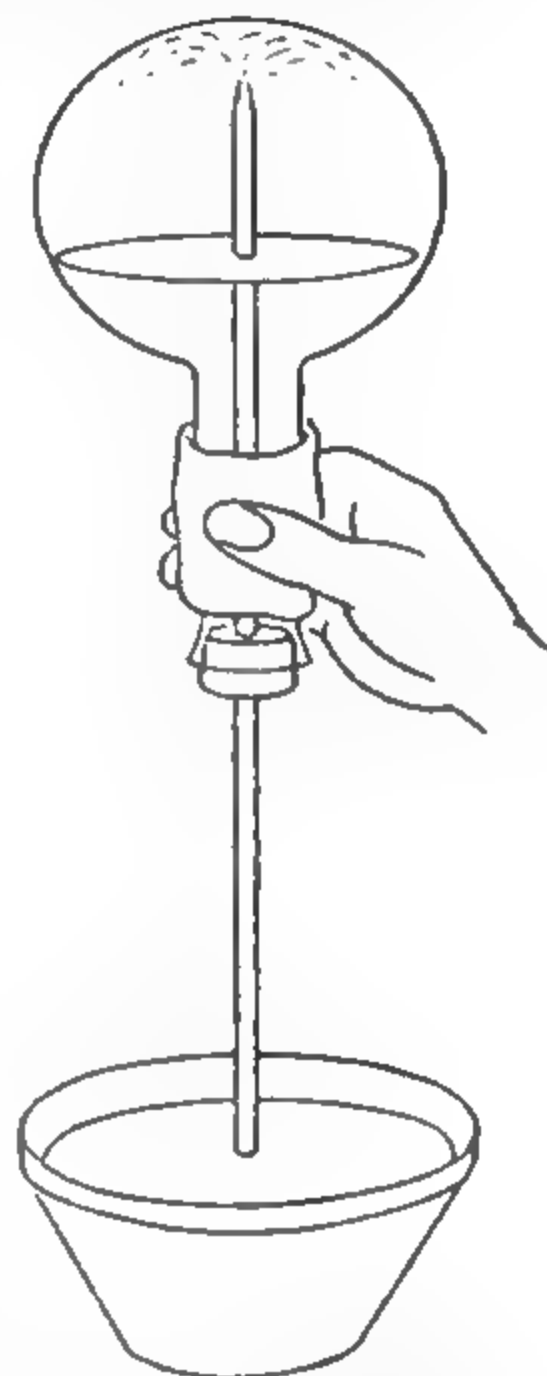


FIG. 42. METHOD OF MAKING A FOUNTAIN

The explanation of this experiment is that the steam drives the air out of the flask. When the flask is removed from the flame the steam inside condenses and leaves a vacuum in the flask. The water rushes up to fill the vacuum.

### *Testing Textiles*

An interesting series of experiments can be carried out with the materials from which various kinds of clothing are made. The principal materials are wool, silk, cotton, and artificial silk. Wool and silk are animal fibres, cotton is a vegetable fibre, while artificial silk is made chemically. There are three chief kinds of artificial silk: viscose, Celanese, and nylon. The simple tests now described will enable you to distinguish between these different fibres. The bristles of many tooth-brushes are nowadays made of nylon, so that an old tooth-brush of this type will provide sufficient material to do the tests given if nylon fabric cannot be obtained.

**Burning.** Put a little of the material into the side of a flame and then remove it from the flame.

Wool, silk, and Celanese burn slowly and stop burning when taken out of the flame. A large black cinder is left on the ends of the fibres.

Cotton, viscose, and nylon burn quickly and continue to burn when removed from the flame. Only a little light ash is left.

**Heating.** Heat a little of each material in a dry test-tube *over a small flame*. As moisture will be given off, hold the tube in a paper holder so that it slopes downward.

All the materials decompose and leave a black residue of carbon. Only Celanese and nylon melt before decomposing. Wool, silk, and nylon give off ammonia gas, which can be recognized by its smell and by putting a piece of damp red litmus paper into the tube. Cotton, viscose, and Celanese give acid fumes, which turn damp blue litmus paper red.

To clean the tubes after use, leave some warm washing-soda solution in them for a while and then clean them out with a test-tube brush.

**Rotting Tests.** (i) *Dilute Sulphuric Acid.* Put a drop of dilute sulphuric acid or sodium bisulphate solution on the material and stretch it over a small flame.

With wool and silk there is practically no change and the material is not rotted by the acid. Cotton, viscose, Celanese, and nylon are all affected. The first three blacken, while the nylon shrivels up almost immediately where the acid was placed.

(ii) *Dilute Nitric Acid.* Repeat the test, using dilute nitric acid this time.

Wool and silk do not shrivel, but the treated parts are stained



yellow. This is the well-known 'xanthoproteic acid test' for a class of chemicals called proteins. These are nitrogen-containing compounds (present in wool and silk) which act with nitric acid to give yellow xanthoproteic acid. Strong nitric acid produces a similar stain on skin. The yellow stain becomes bright orange if ammonia is dabbed on it.

Cotton is not affected by the nitric acid test, but viscose, Celanese, and nylon quickly shrivel, leaving a yellow margin round the treated area. This test distinguishes cotton from viscose.

**Sodium Hydroxide.** Boil a small piece of the material with about an inch of dilute caustic soda solution in a test-tube.

Wool and silk break up into separate fibres and gradually dissolve. Cotton, viscose, Celanese, and nylon are not visibly changed by dilute sodium hydroxide.

### *Indicators from Plants*

At p. 41 we described the preparation of a home-made indicator from beetroot. Indicators can also be obtained from many common flowers and fruits by boiling them with water for a few minutes. The best flowers to use are those which have a deep red or purple colour. Suitable flowers are carnations, sweet peas, geraniums, roses, snapdragons, pansies, tulips, campions, and willow-herb.

Boil a red carnation with a little water in a beaker or small saucepan for two or three minutes. Allow the liquid (which is a reddish purple in colour) to cool and pour it off. Test a few drops of the liquid in a test-tube with a drop of dilute ammonia or washing-soda solution. The liquid will turn bright green with the alkali. To the same tube add a solution of an acid drop by drop. When the alkali has been neutralized the liquid will become light red. Addition of more alkali will turn it green again.

When the indicators obtained from different flowers are tested as above with acid and alkali it will be found that the colour changes are not always the same. While red is a common colour obtained with acids, the colour given by alkalis may be yellow, green or purple.

Red cabbage is well known for its ability to yield an indicator. Less well known, perhaps, are tomatoes, blackberries, damsons, and elderberries. If the fruits themselves are not available, you can in some cases use jam made from the fruit. Thus a saltspoonful of blackberry jam or jelly dissolved in an egg-cupful of warm water gives an indicator which is bright red with acids and a greenish purple with alkalis. The indicator obtained by boiling tomato skins with water is colourless in acid solution but is turned deep yellow by alkalis.



*Changing the Colour of Flowers*

Have you ever seen blue roses or green sweet peas? You can put this question to a friend who is keen on gardening and then astonish him by actually showing him these very unusual flowers. All you have to do is to damp a wad of cotton-wool with a few drops of strong ammonia and put the wad into a jam-jar with the flowers mentioned. Red or pink flowers should be used. If they are kept in the ammonia fumes for only a few minutes they will change colour and will not be injured.

In a similar way you can change the colour of many other kinds of flowers. Those which are white, pink, red or purple are most easily affected. White flowers will turn to yellow, red or purple flowers to green or blue. You can carry out these colour changes with wild flowers or with flowers from the garden.

Some white flowers can be changed to pink by placing the stems in water containing a few drops of red ink. This works well with flowers of the daisy family, including daisies themselves and marguerites.

*Luminous Pebbles and Luminous Sugar*

Next time you are on the sea-shore look out for milky-white pebbles (sometimes coloured yellow by traces of iron). These pebbles are made of quartz, a form of sand. When rubbed briskly together in the dark they give off bright streaks of light, and at the same time there is a peculiar smell like that of burning rubber. If you collect half a dozen of the pebbles (the larger the better) you are certain to find three or four which show this curious property.

A similar effect is obtained when a lump of sugar is ground up in a mortar with a pestle in the dark. Brilliant flashes of light are seen, as if the sugar were on fire. There is no danger of igniting the sugar, however, because very little heat is given out.

*Freezing Water without Ice or Snow*

Some chemicals when dissolved in water give out heat and cause an increase in temperature. Others, when they dissolve, absorb heat and cause the temperature to drop. By mixing together suitable chemicals and dissolving them, a solution can be made which has a temperature well below  $0^{\circ}\text{C}$ . and can be used to freeze water.

Put some cotton-wool at the bottom of a beaker or cup. Place a small tin inside and pack it round with cotton-wool, as shown in Fig. 43. Have ready a test-tube containing not more than half an inch of water. Measure out half an egg-cupful of powdered ammonium chloride and an equal amount of powdered washing-soda crystals. Mix the two together and put the mixture into the tin.

Pour into the tin three-quarters of an egg-cupful of cold water. Introduce the test-tube containing water and use it to stir the mixture in the tin. In about a minute the water in the test-tube will be frozen into solid ice.

### *Getting a Quart into a Pint Pot*

This seemingly impossible feat is quite easy to carry out—if you choose the right materials. The materials are sawdust and water. You do not need to do the experiment with a pint pot, as it is equally convincing if carried out on a smaller scale.

Take two egg-cups of about equal size. Fill one with sawdust and the other with water. Pour half the sawdust on to a piece of paper, leaving the egg-cup half full. Put a glass tube or fountain-pen filler into the water and transfer a few drops of water to the sawdust in the egg-cup. Continue adding the water in this way until about half of it has been transferred to the sawdust.

Now add to the egg-cup the sawdust from the paper and level it off with a knife. Proceed with the transferring of the water as before until only a few drops of water remain. The last few drops can be poured on to the sawdust from the egg-cup down the side of the glass tube. If the last part is carefully performed, the whole of the water can be transferred without spilling a single drop. You have now got an egg-cupful of water and an egg-cupful of sawdust into a single egg-cup, which is equal to putting a quart into a pint pot.

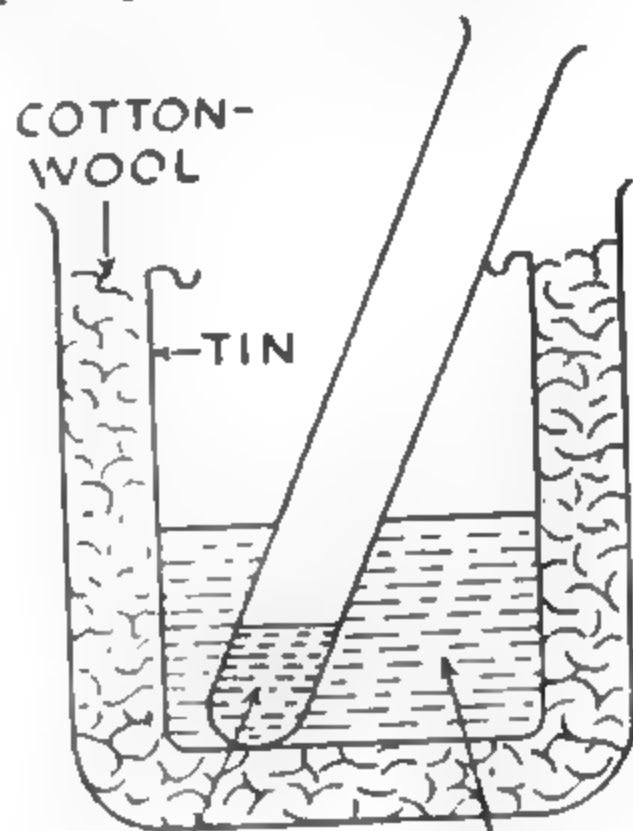


FIG. 43. METHOD OF FREEZING WATER BY CHEMICALS

### *Making Wood Charcoal*

Wood charcoal is made by heating wood away from the air so that it does not burn. The process is sometimes called the 'destructive distillation' of wood. When wood is heated in this way it yields three kinds of products—a solid, a liquid, and a gas. These are respectively charcoal, wood-tar, and wood-gas.

The experiment is best done with a hard-glass test-tube, but if this is not available an ordinary test-tube can be used if it is not heated too strongly. Fill the tube about one-third full with small pieces of wood or sawdust. Fit the tube with a cork, through which passes a short right-angled piece of glass tubing (Fig. 44). Fasten

the tube loosely in a clamp or hold it in a paper holder. It is essential that the tube should slope down slightly or the tarry liquid will run back and crack the glass.

Warm the tube over a medium Bunsen flame, taking care to move the flame about under the tube in the early stages of heating. The wood will soon turn black, and a brown tar will collect in the lower end of the tube. The inflammable gas which is given off can be ignited at the end of the glass tubing.

When the chemical action has finished allow the tube to cool, being careful not to tip up the tube so that the tar runs back. When

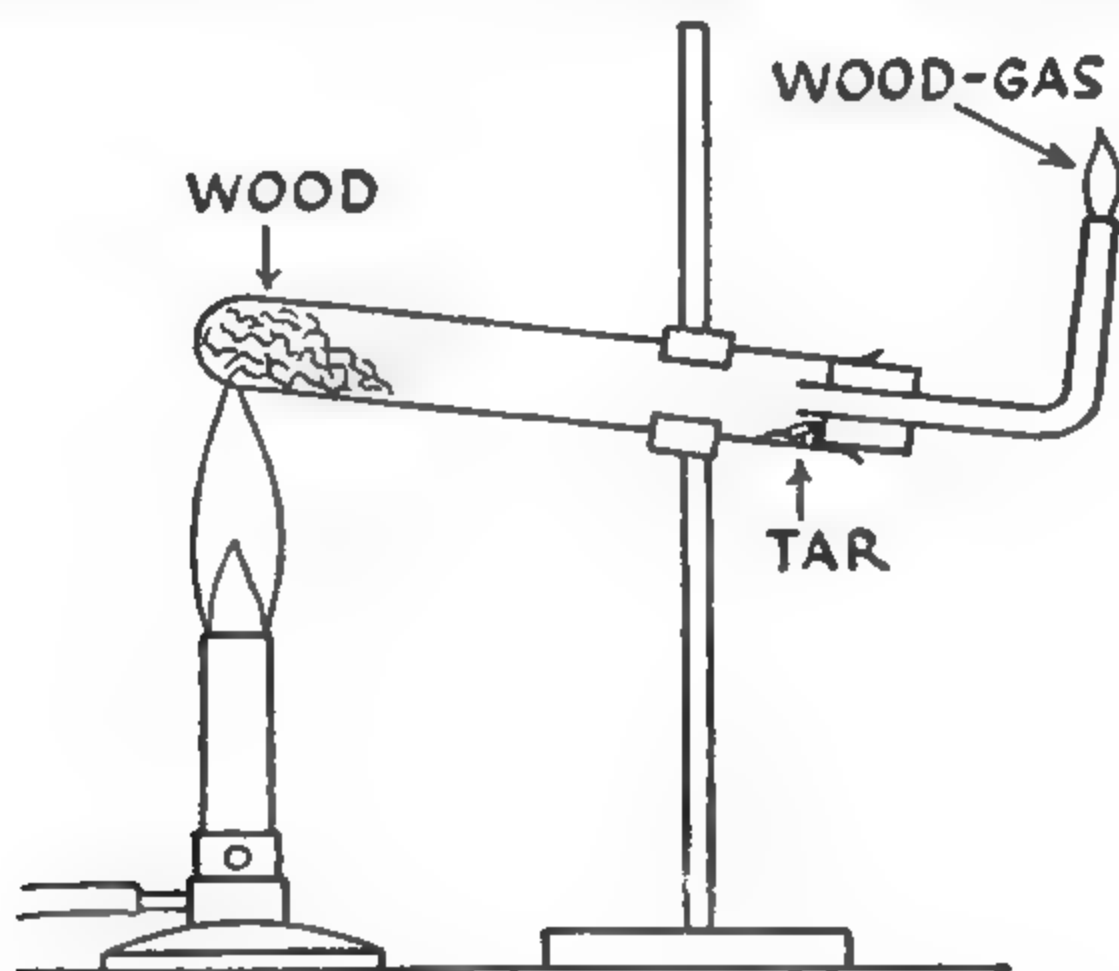


FIG. 44. METHOD OF MAKING WOOD CHARCOAL

the tube is cool remove the cork and run the tar into an egg-cup. Test the brown liquid with a piece of blue litmus paper. The paper will turn red, because the tar contains acetic acid. Tap out the charcoal which remains in the tube on to a piece of paper. The charcoal can be used for some of the experiments described at p. 67.

The tube which has been used in this experiment should be cleaned out immediately afterwards with hot soapy water or washing-soda solution.

### *Ammonia from Soot*

Scrape a little soot from the back of the chimney into a saucer. Put about an inch of the soot into a test-tube and warm it with a little washing-soda solution or dilute sodium hydroxide. Ammonia gas will be given off and can be recognized by its smell and by turning damp red litmus blue. Soot is a valuable fertilizer for the garden on account of the ammonia which it contains.

*The Chemicals in the Blue-bag*

A blue-bag is often used at home on wash-days to give a slight blue tint to the clothes. The blue tint counteracts the yellowish tinge which white clothing acquires with age. The blue-bag usually contains two chemicals, sodium bicarbonate and a deep blue substance called ultramarine. The latter is manufactured by heating together white china-clay, sodium carbonate, sulphur, and charcoal. In spite of the fact that ultramarine is used for colouring clothes, it is quite insoluble. Because of this the two chemicals in the blue-bag can be separated.

Powder a little of the material from the blue-bag with the back of a spoon on an old newspaper. Put about an inch of the powder into a test-tube and fill the tube to about half-way with water. Shake the tube for two or three minutes to dissolve the sodium bicarbonate and then filter the liquid. The filtrate will be a perfectly colourless solution, and the insoluble ultramarine will be left in the filter-paper. To show that the solution contains sodium bicarbonate, test it with red litmus paper. The paper will turn blue. Add a few drops of any dilute acid to the solution. There will be effervescence due to the giving off of carbon dioxide.

Add a drop or two of dilute acid, also, to the ultramarine in the filter-paper. The blue colour will be at once destroyed. Ultramarine is very sensitive even to the weakest acid. For this reason sodium bicarbonate is incorporated with it in the blue-bag, so that when it is used in washing the water is kept slightly alkaline by the sodium bicarbonate.

*Home-made Tooth-powder*

The following tooth-powder is cheap to make, and will whiten your teeth better than most of the expensive pastes and powders sold for the purpose.

In a dry jam-jar mix together with a large spoon an ounce of powdered (precipitated) chalk and an ounce of powdered wood charcoal. Both of these materials can be bought as fine powders for a few pence at a chemist's. Transfer part of the mixture to a small jar and use the material from this jar, refilling the latter as required. The amounts stated should last you for a couple of months.

*Home-made Toffee Crunch*

The following recipe for a very toothsome kind of toffee (the author has tried it!) depends on the giving off of carbon dioxide gas by baking-soda when heated.

Put two tablespoonfuls of sugar and two tablespoonfuls of syrup (or treacle) into a small saucepan. Bring the mixture slowly to the

boil over a small flame while stirring with a spoon. Continue the boiling and stirring for six or seven minutes. Then remove the pan from the flame and stir in a small level teaspoonful of sodium bicarbonate. The contents of the saucepan will froth up as carbon dioxide is given off. Pour the toffee into a greased tin, allow it to cool, and break it up into pieces.

### *Experiments with Camphor*

Camphor is an organic substance with the chemical formula  $C_{10}H_{16}O$ . It is used for making celluloid (p. 205) and for killing moths in wardrobes and drawers. At one time it was obtained only from certain trees growing in Formosa and Japan, but nowadays it is made synthetically from chemicals. A small block of camphor can be bought from the chemist's for about sixpence.

(i) Fill a large bowl with water and place a piece of camphor about the size of a pea on the surface. Apply a light to the camphor. The latter will set on fire and move about rapidly on the surface of the water. If the experiment is performed in the dark the effect is quite weird. The camphor will continue to burn for a long time, with a smoky flame due to the high percentage of carbon which it contains.

(ii) When gently warmed camphor sublimes readily. This can be shown by the same method as described for naphthalene (p. 108).

(iii) Camphor is almost insoluble in water but dissolves readily in methylated spirit. Put a small piece of camphor into a dry test-tube with about half an inch of methylated spirit and shake the tube. The camphor will quickly dissolve. Pour the solution into some water in a test-tube. A white precipitate of camphor will be formed.

### *How to remove Stains*

A knowledge of how to get rid of stains is extremely useful to the chemist, because most people regard him or her as an authority on the subject. From time to time ink gets spilled on clothes or accidents occur with chemicals, and you will increase your prestige enormously if you know how to remove the unsightly marks which result. A few words of general advice will first be given.

Treat stains as quickly as possible. The older the stain the more difficult it is to remove. If the matter causing the stain (*e.g.*, tar or paint) is caked on to the material, scrape off as much of it as you can with an old knife before applying treatment. Methods of treatment fall under two headings: (i) use of solvents, and (ii) use of chemicals. Warm water is a solvent which will remove many stains, but if the marks are caused by a greasy or oily substance such as tar

it will be necessary to use a solvent like Thawpitt or carbon tetrachloride. Benzene and petrol are often used to get rid of grease or oil marks, but these liquids are not recommended, because they are dangerously inflammable. *They must never be used in a room where there is a fire or naked light of any kind.* This warning applies also to people smoking in a room. A considerable number of deaths through burning occur every year because this precaution is neglected.

**Non-greasy Stains removed by Water.** These include stains due to tea, coffee, treacle, jam, fruit, and blood. Warm water should be used, except in the case of blood-stains, which should be treated with *cold* water. If the stain is not completely removed by water, it should be soaked afterwards in hydrogen peroxide to which ammonia solution has been added (see later).

**Removal of Grease, Oil, and Tar Stains.** If the stains are only slight it is possible to get rid of them by soaking in warm soapy water for a time. For more severe stains it is necessary to use a solvent like the proprietary liquid Thawpitt or carbon tetrachloride. The latter is the cheaper if it is bought from a chemical dealer. These liquids are non-inflammable, but should not be used in a place (like a cellar) where there is little or no ventilation, because the vapours are unsafe to breathe. They are also effective with stains caused by black or brown shoe-polish.

In applying the treatment, put two or three folds of a clean rag or blotting-paper at the back of the stain and apply the liquid to the stain with a wad of cotton-wool. The staining matter will be washed out and absorbed into the rag or blotting-paper. If the stain is large change the rag or blotting-paper below the stain after a time and continue the treatment.

Stains due to an oil-paint are best removed by means of turpentine or turpentine substitute, which is sold at the ironmonger's. The method of treatment is the same as described in the previous paragraph.

**Stains removed by Methylated Spirit.** Grass stains are readily removed by this solvent. Stains caused by dyes can often be removed by methylated spirit to which one or two drops of strong ammonia solution have been added. An absorbing pad should be placed below the stain as previously described. Marks due to violet marking ink should also be treated with methylated spirit, any slight colour remaining being got rid of by chemical treatment with hydrogen peroxide or bleaching fluid (see next section).

**Chemical Treatments.** Some of these involve the use of bleaching liquids, such as bleaching fluid (sodium hypochlorite), chloride of lime, and hydrogen peroxide. The first two of these should not be used on woollen materials such as flannel trousers, because they



destroy the material. In every case the material after treatment should be washed well in water to remove the chemical.

(i) Iron mould. This can be removed by soaking the stain in a solution of citric acid for a time. Use a solution containing a teaspoonful of citric acid dissolved in an egg-cupful of warm water. Lemon-juice can also be used, but this takes longer, as it is a weaker solution of citric acid.

(ii) Blue-black writing-ink. First wash out as much of the ink as possible with warm water. If the stain is fresh and only slight it can be removed by soaking it in milk for a while. More severe stains are removed by soaking them in a solution of hydrogen peroxide to which a few drops of strong ammonia have been added. A suitable strength of hydrogen peroxide is one part of the 20-volume solution to three parts of water. Solutions of bleaching fluid and chloride of lime are also effective. In the first case dilute the strong bleaching fluid to five or six times its volume with warm water; in the second stir a teaspoonful of chloride of lime with an egg-cupful of water for a few minutes and pour off the clear liquid, which is then applied. For ink-stains on wooden surfaces apply a paste of chloride of lime and water. Leave the paste on the stain for a time and then remove it with a wet cloth.

If the stain is old the chemical treatments described above may leave a brown stain due to iron in the ink. Remove this by the method described for iron mould.

(iii) Red ink. There are many types of red ink, and treatment which is successful in one case does not necessarily work in another. The best thing to do is to try in order the following: warm water, methylated spirit, hydrogen peroxide, bleaching fluid or a solution made from chloride of lime.

(iv) Scorch marks. If these are not too severe they can be removed with hydrogen peroxide. Severe scorch marks cannot be removed entirely, but the brown colour can be made paler by applying hydrogen peroxide.

(v) Laundry blue. Vinegar or any weak organic acid like citric acid should be applied.

(vi) Iodine. This stain is easily removed by treatment with a dilute solution of 'hypo' (sodium thiosulphate) or washing-soda.

### *Chromatography*

#### (A New Method of Chemical Analysis)

Chromatography—which means literally 'colour-writing,'—is a new tool in the hands of the analytical chemist. It was discovered by a Russian called Tswett in the early part of the present century, but it has only come into general use since about 1930. It is extremely

useful in separating and identifying substances when other methods, like fractional crystallization or fractional distillation, are difficult or impossible.

Chromatography depends on the ability of certain powdered chemicals to make substances stick to the surface of their particles. This property, which has already been noted with charcoal (p. 67), is called 'adsorption.' Tswett carried out his original experiments with chalk (calcium carbonate), but aluminium oxide is the powder most commonly used nowadays.

It is easy to perform some simple but interesting experiments at home on chromatography if you have some powdered chalk or starch. The only apparatus needed is a test-tube with a hole in the bottom, and this you are likely to acquire in the course of your other experiments. Cover the hole by pushing a small plug of cotton-wool to the bottom of the tube with a rod or pencil. Fill the tube to just over half-way with fine starch or chalk (known to the chemist as 'precipitated' calcium carbonate) and pack it into an even layer by pushing it down with a pencil. To obtain good results, even packing of the powder is needed, but it should not be packed so tightly that liquid cannot soak through it.

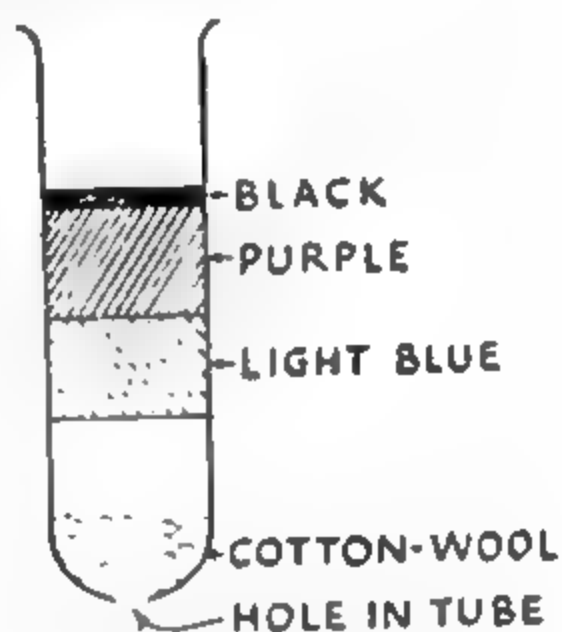


FIG. 45. CHROMATOGRAM FROM BLUE-BLACK INK WITH CHALK

Ordinary blue-black writing-ink can be used satisfactorily with the prepared tube. Mix a thimbleful of ink with a thimbleful of water and pour three drops of the mixture into the test-tube. Stand the test-tube in a jam-jar. In a few minutes the ink will have soaked down into the fine white powder and will have stained it. You will find, however, that the powder has been stained different colours in different parts. At the top there will be a narrow black ring. This will be followed by a longer purple layer, and this again by a light-blue layer (Fig. 45). The boundary between the different layers can be made sharper by adding a little water to the test-tube and letting this soak through the powder.

Each of the layers in the tube corresponds to a separate constituent of the ink. The black constituent is adsorbed by the powder most readily, followed by the purple and light-blue constituents. Thus in this experiment the colouring-matter in the ink is separated into the three substances which make it up. The set of coloured layers in the tube is described as a 'chromatogram.'

The same experiment can be performed with red ink, but the results vary considerably with the make of ink. In some cases only one coloured layer is obtained, showing that only one dye is present

in the ink; in others two or three differently coloured bands—red, orange, and yellow—reveal that the ink contains more than one dye. It is interesting to mix together a little red ink and blue-black ink and filter the mixture through the chalk or starch. You will obtain a chromatogram corresponding to the two kinds of ink.

Other solutions which yield interesting chromatograms are log-wood extract, cochineal solution, and extracts made by boiling coloured flowers with water.

Calcium carbonate is not a suitable material to use for experiments in chromatography with most of the ordinary chemicals mentioned in this book. This is partly because many of them act chemically with the chalk (the use of powdered starch overcomes this difficulty). Again, many chemicals are colourless, and, although they are adsorbed by chalk, the layers cannot be seen. One coloured mixture, however, which can be separated with chalk is a mixture of copper sulphate and cobalt chloride solutions. The mixture will give a blue layer, due to copper sulphate, followed by a pink layer, due to cobalt chloride.

If you are interested in the subject of chromatography you can find out more about it in a book called *An Introduction to Chromatography*, by Trevor S. Williams (Blackie, 1946).

### *Making 'Smoke-rings' with Ink-drops*

Most readers will have seen smoke-rings produced by blowing cigarette smoke out of the mouth. Similar rings—but far prettier ones—can be made by dropping ink into water, as now described.

Nearly fill a jam-jar with water and leave it until the water has become still. For adding the ink-drops use a dropping-tube (p. 36) or a small syringe. If neither of these is available fold a filter-paper (or even a piece of newspaper) as for filtering and pour a few drops of ink into the paper. Allow a single drop to fall into the water from a height of about an inch. A perfect ring will be formed in the water, but as the ring falls it will break up into several smaller rings, each one being perfect in shape. A second drop of ink will behave similarly.

Repeat the experiment, using fresh water in the jar, but this time dissolve a teaspoonful of salt in the water. Again wait until the liquid has become still before allowing the ink to fall. Rings will be produced as before, but this time, instead of falling to the bottom, they will remain suspended in the liquid and you will have time to examine them. You will be surprised by their beauty. If you have any other coloured inks you might try the experiment with these.

## CHAPTER VII

### *Growing Crystals at Home*

CRYSTALS are one of the best examples of the beauty of Nature's handiwork. Few people are indifferent to the sparkle of a crystal, whether it be a princely diamond or only a humble snowflake. No experiments in Chemistry give greater pleasure to the keen experimenter than the growing of crystals, and to build up a set of crystals which can be kept affords a lasting satisfaction.

The growing of crystals is usually considered too difficult a proposition for amateur chemists to attempt. The author, however, has devised methods which make it easy for boys to grow crystals of common chemicals at home. The illustrations in Plates 4 and 5 show how successful these methods can be.

Apart from a funnel, filter-papers, and the necessary chemicals, no special materials are required. Two or three crystallizing-vessels are needed, but the small-size glass pots in which fish-pastes are sold serve admirably for the purpose. The most important factors are time and patience, for large crystals cannot be grown in a few days. While some of the crystals shown in Plates 4 and 5 take only a few weeks to grow, others require a period of three or four months. However, if you are prepared to take the trouble, you can make a set of crystals of which you can feel justifiably proud.

Now, a man cannot start to build a house without knowing something about bricks and mortar and building-construction. Similarly, if you are going to grow crystals successfully, you must have some knowledge of crystals. We shall therefore describe briefly what crystals are and how they are formed.

#### *What Crystals are*

Most chemicals, whether they are elements or compounds, can exist as crystals. Furthermore each substance usually adopts a particular crystalline shape, although very often the same shape is adopted by crystals of different substances. Thus the natural shape of both a diamond and an alum crystal is octahedral (eight-sided), as illustrated in Fig. 47. We never see diamonds in their natural shape in everyday life because the diamonds have been cut to increase their sparkle, but when we grow crystals we obtain them in the form designed by Nature.

It is usually necessary to grow crystals under the right conditions before their crystalline shape can be observed. A so-called 'crystal'

of copper sulphate in your stock-bottle consists of many thousands of very small crystals joined together just anyhow. When a crystal of copper sulphate is grown in a solution under suitable conditions the molecules fit together in a regular pattern, like soldiers on parade, and produce a definite shape of crystal with flat—never curved—faces. In many of the experiments described in previous chapters chemicals have been crystallized out. Generally, however, they will not have been obtained in their true crystalline form because they have not been grown under the proper conditions.

Some crystals are easier to grow in their true shape than others. Large crystals of common salt and washing-soda are very difficult to grow, and you will waste your time if you make the attempt. Again, many substances form needle-shaped crystals very readily. This is called the 'needle habit,' but such crystals do not represent a true crystalline shape. 'Needles' are formed as the result of the crystals growing out lengthways along two or three faces instead of growing in the right proportion on all the faces. The crystals obtained, therefore, are distorted or out of shape. Good examples of the needle habit are shown by ammonium chloride (p. 60), sodium sulphate (p. 97), and magnesium sulphate (Plate 4).

Some further information on the structure of crystals is given at the end of this chapter.

### *Practical Hints on growing Crystals*

Big crystals grow from small ones, so that our first task is to obtain some small crystals of good shape. The chief methods of crystallizing a substance have been used in experiments described in the earlier part of this book. These methods include: allowing a melted substance to cool and solidify—*e.g.*, ice, p. 146; precipitation—*e.g.*, boracic acid, p. 63; sublimation—*e.g.*, iodine, p. 78; crystallizing from a solution—*e.g.*, alum, p. 55. Only the last of these methods is employed to obtain the small crystals which we use as the starting-points for growing large crystals.

In order to obtain the small crystals from a solution, the following important principles should be remembered:

(i) Crystals of a substance can only be deposited from a solution after the solution has been saturated with that substance.

(ii) Nearly all solids are more soluble in water at a higher temperature and less soluble at a lower temperature.

(iii) Before a crystal can form, even in a saturated solution, there has to be present a 'nucleus' around which the crystal can form. The nucleus is a tiny particle possessing the same shape as the crystal. It may result from the molecules in solution coming together by accident in just the right way to start a crystal forming. More often



it is provided by a chance particle of dust in the liquid. If the solution is dirty there will probably be a lot of nuclei present, with the result that many small crystals will form; but these will be too small to do anything with. Solutions should therefore be filtered and protected from dust.

(iv) Rapid crystallization occurs when a saturated solution is evaporated or cooled quickly. Again it produces a useless mass of very tiny crystals. Gradual crystallization, by means of slow evaporation or cooling, results in fewer but larger crystals. It is the latter result which we wish to achieve.

The reader will notice how the above principles are used in the instructions given in the following pages.

The usual method described for growing a large crystal from a small one is to tie a piece of cotton round the small crystal and hang it in a saturated solution of the same chemical. As water evaporates from the solution fresh layers of the chemical are deposited on the crystal. For this method to be successful the temperature must remain absolutely steady. This condition is impossible to realize except in special circumstances. Sooner or later the weather will become warmer, the temperature of the solution will rise, and the crystal which may have been growing satisfactorily for a week will dissolve in the solution (now unsaturated owing to the rise in temperature).

The author's method is to grow the crystal always *with a falling temperature*. Briefly, the method is to put the crystal into the saturated solution (usually slightly warm) at night and take it out in the morning. It is rare for the weather to become warmer during the night. Usually the temperature falls, with the result that solid is deposited from the saturated solution. This method of growing a crystal is more reliable and more rapid than the one usually given in text-books of Chemistry. Even if the temperature does rise, the precautions described will ensure that only slight damage will be done to the crystal, and this can be easily repaired.

The place where you leave the crystal in its solution at night is important. It is best to vary the place according to the time of the year. In winter, when the weather is cold, the most suitable place is inside the house, because then solutions will not cool too quickly. In summer, when the fall of temperature during the night is smaller, the solutions can be left in an outside building such as a wash-house. In the case of one or two substances special precautions have to be observed, but these are mentioned in the appropriate places.

### *An Alum Crystal*

An alum crystal is one of the easiest kinds of crystal to grow. The crystal is octahedral, or eight-sided (see Plate 4), although very often



'cornering' occurs—that is, the crystal grows with one or more of its corners missing, just as if they had been cut off with a sharp razor. This phenomenon of cornering is common with other crystals as well. This will be seen by reference to Plates 4 and 5.

There are three stages in growing a crystal which measures, say, two to three inches along the side.

**Stage I. Obtaining a Small Crystal of Good Shape.** First you will have to make a saturated solution of alum. This can be done in two ways. You can heat some alum with water in a beaker and afterwards cool the solution or you can leave the alum in the water in a beaker or jam-jar for twenty-four hours, occasionally stirring the liquid. In either case use a tablespoonful of the powdered chemical to about half a cupful of water and add half a dozen drops of dilute sulphuric acid or sodium bisulphate solution. The acid is not absolutely necessary, but in its absence the alum will become slightly decomposed by the water after a few days and the solution will no longer be clear. When the saturated alum solution is cold some of the solid substance should remain undissolved.

Filter off enough of the solution to fill your small crystallizing-pot (which should be clean) to a depth of only quarter of an inch. In filtering, omit the usual preliminary wetting of the filter-paper (p. 27). Cover the pot with a piece of cardboard in which half a dozen holes have been pierced with a pencil point and leave the pot standing on several folds of paper on a shelf. Cover the beaker or jar which contains the remainder of the saturated solution and leave it beside your crystallizing-pot.

At the end of another twenty-four hours you will probably find that a few diamond-shaped crystals have been deposited on the bottom of the crystallizing-pot. If this has not happened, remove the cardboard cover and leave the vessel for a further period until the crystals appear. Pour off the liquid from the crystals. With the point of a penknife transfer three or four crystals (not necessarily the largest) which have the best diamond shape to a piece of filter-paper and dry them. (An electric torch shone upward through the bottom of the dish will enable you to see the crystals clearly.) Wash out and dry the crystallizing-pot.

The next step is to obtain a crystal large enough to tie a piece of cotton round. We now begin to make use of the principle of the falling temperature. At night again filter sufficient of the saturated solution to fill your crystallizing-pot to a depth of quarter of an inch. Place the three or four crystals in the dish, spacing them so that they do not touch. Cover the dish with cardboard as before and leave it overnight. The following morning pour off the liquid and dry the crystals on filter-paper. The crystals will have grown appreciably

larger, and you should now have at least one measuring  $\frac{1}{8}$  inch across, which is large enough to tie cotton round.

**Stage II. The Cotton Stage.** We describe the stage in this way because each night the crystal is suspended by cotton in the saturated solution. Thin mending-silk will do equally well. The best colour of cotton or silk to use is white.

To tie one end of a length of cotton round a small crystal is a ticklish job, but with a little patience it can be managed so that the crystal is held securely. Make a small hole in the middle of a wood spill or gardener's wooden label. Thread the other end of the cotton through the hole and fasten this end to a pin. Insert the pin into the wood at a suitable place, so that the crystal will be suspended in about the middle of the pot (see Plate 4). This arrangement makes it possible to raise or lower the crystal in the solution as required.

In the early part of the evening nearly fill the crystallizing-pot with saturated alum solution from your stock and introduce also into the vessel a thin layer of the powdered solid. Leave the pot for two or three hours in a warm place—such as on the hearth or in the airing-cupboard—and stir the solution every hour or so. Be careful not to spill the solution on carpets or clothes, or it will 'burn' a hole (if any of the liquid is accidentally spilled, treat it at once with dilute ammonia or baking-soda). Before you go to bed transfer the crystallizing-pot to a cool place and allow it to cool for ten minutes before suspending the crystal in the solution, as shown in Plate 4. Leave the crystal thus suspended overnight. All you have to do the following morning is to lift the crystal, wood spill, and pin from the pot and dry the crystal with a piece of filter-paper or blotting-paper.

The next evening again slightly warm the solution, as described previously, and replace the crystal in the liquid before you go to bed. Again remove the crystal in the morning. In this way the experiment will require only a few minutes' attention at night and in the morning. Each morning you will find that the crystal has increased in size because solid has been deposited on it from the solution owing to the fall in temperature. Removal of the crystal in the morning will guard against the daytime rise in temperature. A few drops of fresh saturated solution of alum should be added to the dish from your stock, as required.

Sometimes you will notice that small irregular growths form on the faces of the crystal. These growths are caused by chance particles of dust attaching themselves to the crystal faces and acting as nuclei for new growths. The irregular growths should be gently rubbed away with *fine* sandpaper, after which the face of the crystal should be wiped over with a damp cloth.

Small alum crystals are always formed on that part of the cotton which is in contact with the solution. These crystals should be removed. This can be done by laying the crystal and cotton on a newspaper and crushing the small crystals on the cotton with a pen-knife handle, after which any remaining substance can be gently rubbed off.

In a week or two the crystal will have grown too big for the small crystallizing-pot. Growing is now continued in a somewhat larger pot, which will suffice until the crystal measures about one inch along the side. This should take about a month. After this you can bring a jam-jar (one-pound size) into service. The jam-jar can be used until the crystal has edges about two inches long. It is a good idea, however, never to use a volume of solution which is much larger than the crystal. If then something does go wrong (the temperature may occasionally rise during the night) only slight damage will occur to the crystal. This usually shows itself in the rounding of the edges and corners of the crystal because the crystal tends to dissolve most easily at those parts. Providing the dissolving is not too great, the loss will be made good in a night or two.

From time to time during the growing of the crystal the cotton used for suspending will rot and become weak. It should be changed before it breaks. Cut off the cotton where it enters the crystal with an old razor-blade and attach a fresh length to the crystal and pin. As the crystal becomes larger it is best to make a slip-knot in the cotton which is then slipped round the crystal and drawn tight. Attach the cotton so that the faces of the crystal which were previously uppermost in the solution now point downward. This will counteract a tendency for the lower faces of the crystal to grow more rapidly and will keep the crystal in good shape.

**Stage III. Growing a Very Large Crystal.** Perhaps most boys will be satisfied with the size of the crystal which they have obtained at the end of Stage II and will wish to start growing a crystal of another substance. For those who desire to continue the growth of the alum crystal still further, the method of proceeding is given.

We now abandon the cotton method of suspending the crystal and continue the growing in a basin. A basin with a rounded bottom and measuring about four inches across the top and three inches deep is suitable, although larger basins can be used later when required. With a few differences, the same method of putting the crystal into the slightly warm saturated solution at night and taking it out in the morning is followed.

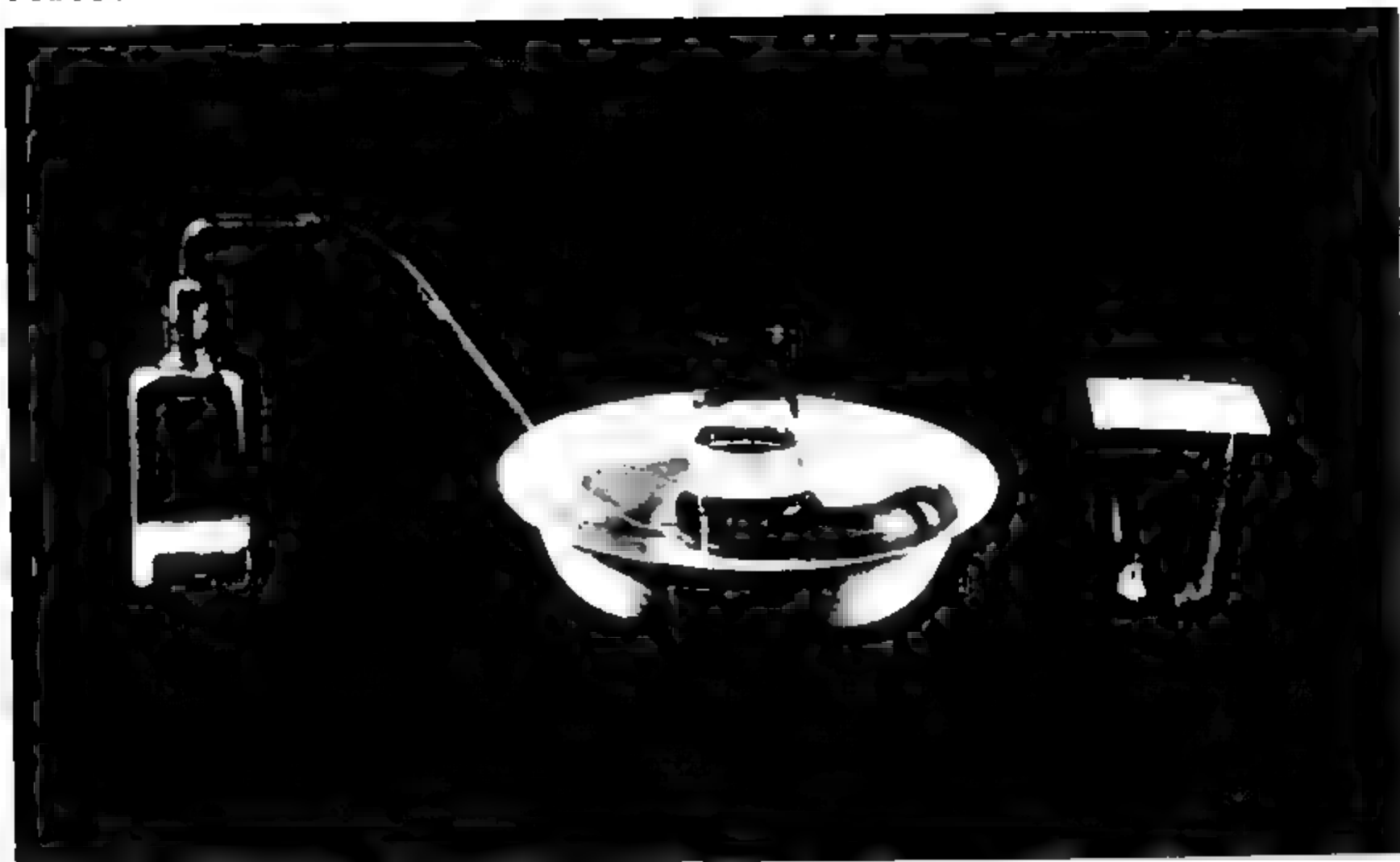
You will now require sufficient saturated solution nearly to fill a two-pound jam-jar. When making the new saturated solution leave



HOMI-GROWN CRYSTALS OF COPPER SULPHATE (DARK) AND A  
COPPER AMMONIUM SULPHATE (LIGHT BLUE)



HOMI-GROWN CRYSTALS OF FERROUS SULPHATE (GREEN) FERROUS  
AMMONIUM SULPHATE (GREEN) AND A CRYSTAL OVERGROWN WITH  
(POTASH ALUM ON CHROME ALUM)



• • •



1. The first step is to identify the problem. In this case, the problem is that the company is not meeting its sales targets.

the powdered solid in contact with the water (plus a little dilute sulphuric acid) in the jar for at least two days, with occasional stirring to ensure saturation. Never risk putting the crystal into the solution unless you are certain that the solution is saturated. Otherwise you may undo a month's work in the course of a single night.

Each night leave the solution and a layer of solid alum in the jar in a warm place for two or three hours and stir the liquid every hour or so with a tablespoon. Place the crystal in the basin so that four corners rest on the side of the basin. Before bed-time pour the slightly warm solution into the basin down the spoon until the crystal is covered with the liquid to a depth of about half an inch. Leave the basin on a shelf.

In the morning arrange two or three folded newspapers on top of each other. Pick up the crystal from the solution with your fingers and, holding it over the basin, rub a finger lightly over the faces to remove any loosely attached solid particles. Lay the crystal on the newspaper and wash your hands. Wipe the faces of the crystal with filter-paper or a clean rag kept specially for this purpose. Put the crystal into a saucer and leave it until the evening. Again wash your hands. Throw away the newspaper which is wet with alum solution.

In the evening smooth away any irregularities on the crystal faces by rubbing them with fine sandpaper. Do this on a loose half-sheet of newspaper placed over another newspaper and throw away the half-sheet afterwards. Hold the crystal for a second under the cold water-tap to wash off any powder, and dry the crystal as described previously. Replace it in the basin with a different face uppermost.

Transfer the solution and any solid left in the basin to the large jam-jar once more, and again warm the solution slightly before covering the crystal in the basin at bed-time.

The size to which you can grow your crystal by the method described is limited only by the size of your basins and jars and, perhaps, by the amount of money which you can afford for buying alum. The large crystal of potash alum shown in Plate 4 measures about three inches along the side. This crystal took about four months to grow.

### *Crystals of other Alums*

The substance commonly known as alum is potassium aluminium sulphate (p. 54), and forms colourless transparent crystals. Other substances which are also called alums are chrome alum and iron alum. Both of these chemicals form crystals which are similar in shape to those of ordinary potash alum, but are coloured. Iron alum



crystals are violet, while chrome alum crystals are deep purple. Both are easy to grow and give beautiful crystals. Photographs of these crystals are shown in Plate 4.

The method of procedure in growing the crystals is similar to that described for potash alum. When the saturated solutions are being prepared a few drops of dilute sulphuric acid or sodium bisulphate solution should be added to the water to prevent the slight decomposition of the chemicals by the water.

Iron alum can be bought in two forms, potassium iron sulphate and ammonium iron sulphate (p. 81). The crystals of the latter form grow relatively quickly and are the better kind of iron alum to use. The solution is brown in colour. Care should be taken not to spill the solution about, as it leaves a stain of iron mould. After handling a crystal of iron alum you should wash your hands well and wipe them on an old cloth, not on a towel. Accidental stains can be removed by early treatment with citric acid (p. 152).

Chrome alum is potassium chromium sulphate (p. 69). The saturated solution is blackish purple in colour. There is a tendency for this chemical in solution to pass into a green form, which is difficult to crystallize. Therefore, to economize in the use of the substance, you should not prepare more of the saturated solution than you are likely to require for immediate needs. The change to the green form is hastened by heating, so that it is not advisable to warm solutions of chrome alum more than slightly at any time. Again your hands should be washed well after handling a crystal.

### *Making a Crystal Overgrowth*

This curious example of crystallization requires two chemicals which have similar crystals; potash alum and chrome alum are good substances to use. The experiment consists of growing a crystal of one substance and then growing a crystal of the second substance outside the first. This is called a crystal 'overgrowth.'

First grow a crystal of the purple chrome alum by the method which has been described. When the crystal has grown to a size of about half an inch suspend it at night in a slightly warm saturated solution of ordinary alum and immediately transfer your crystallizing-pot to a cooler place. You must be quite sure that your second alum solution is saturated. Otherwise, instead of the potash alum becoming deposited on your chrome alum crystal, the crystal will start dissolving in the solution. In the morning a colourless layer of potash alum should have been formed round the crystal. If you continue the growing each night you will obtain a transparent crystal of potash alum through which the purple chrome alum crystal can be seen.

An 'overgrowth' of potash alum on chrome alum is illustrated in Plate 5. In this case, after obtaining the double crystal, one half of the crystal has been removed by rubbing with sandpaper so that a cross-section of the double crystal is shown.

### *A Copper Sulphate Crystal*

This is another crystal which is easy to grow by the method described previously. Again, in making the saturated solution, a little dilute sulphuric acid or sodium bisulphate solution should be added to the liquid.

When a crystal of copper sulphate is being grown there is a marked tendency for unsightly irregular growths to form on the faces of the crystal. Once these appear it is difficult to stop their reappearance, even when they are regularly removed with sandpaper. It is a good idea to grow two or three crystals together in the early stages, and then select for further growth that crystal which is most free from blemishes. A copper sulphate crystal is shown in Plate 5.

Copper sulphate solution is poisonous and corrosive if left on clothes or wooden surfaces. It is safe enough to use, however, if ordinary precautions are taken in handling it.

### *A Ferrous Sulphate Crystal*

It is more difficult to grow a ferrous sulphate crystal than the crystals previously mentioned, but this should not deter you from trying. The crystal illustrated in Plate 5 shows what can be done in this case with a little care.

In making a saturated solution it is essential to include a little dilute sulphuric acid or sodium bisulphate solution in the liquid. Ferrous sulphate (both solid and solution) oxidizes in air to the brown ferric sulphate, but this change is prevented in the solution by the addition of the dilute acid.

The small crystal which is to be used as the starting-point for the large crystal can be obtained readily enough as described in the first stage of growing an alum crystal. Stage II requires a slightly different method, however, because it is necessary to grow a ferrous sulphate crystal more slowly than other crystals. Rapid growth results in the depositing of 'seedy' crystals which mar the shape of the crystal as a whole.

When the small crystal has been obtained, and cotton tied round it, suspend it at night in the saturated solution without warming the latter at all. In this way you will make use only of the fall in temperature which occurs during the night. Also put your crystallizing-pot into a larger vessel, such as a cup or a mug, and pack the space

between the two vessels with cotton-wool. This will ensure that the temperature falls slowly and will result in a very gradual depositing of solid on the crystal. Remove the crystal during the day and replace it in the solution at night.

Instead of the faces and edges of the crystal being perfectly smooth, they will be somewhat rough. Remove this roughness each day by gentle rubbing with fine sandpaper. Afterwards wash off any powder on the crystal by holding it for a moment under the cold water-tap

and dry the crystal with filter-paper or blotting-paper.

When the crystal becomes large enough you can pass on to Stage III and continue the growth in a small basin. It takes longer to grow a large crystal of ferrous sulphate than most other crystals. The crystal shown in Plate 5 took about three months to grow.

As with iron alum, ferrous sulphate will cause iron mould if

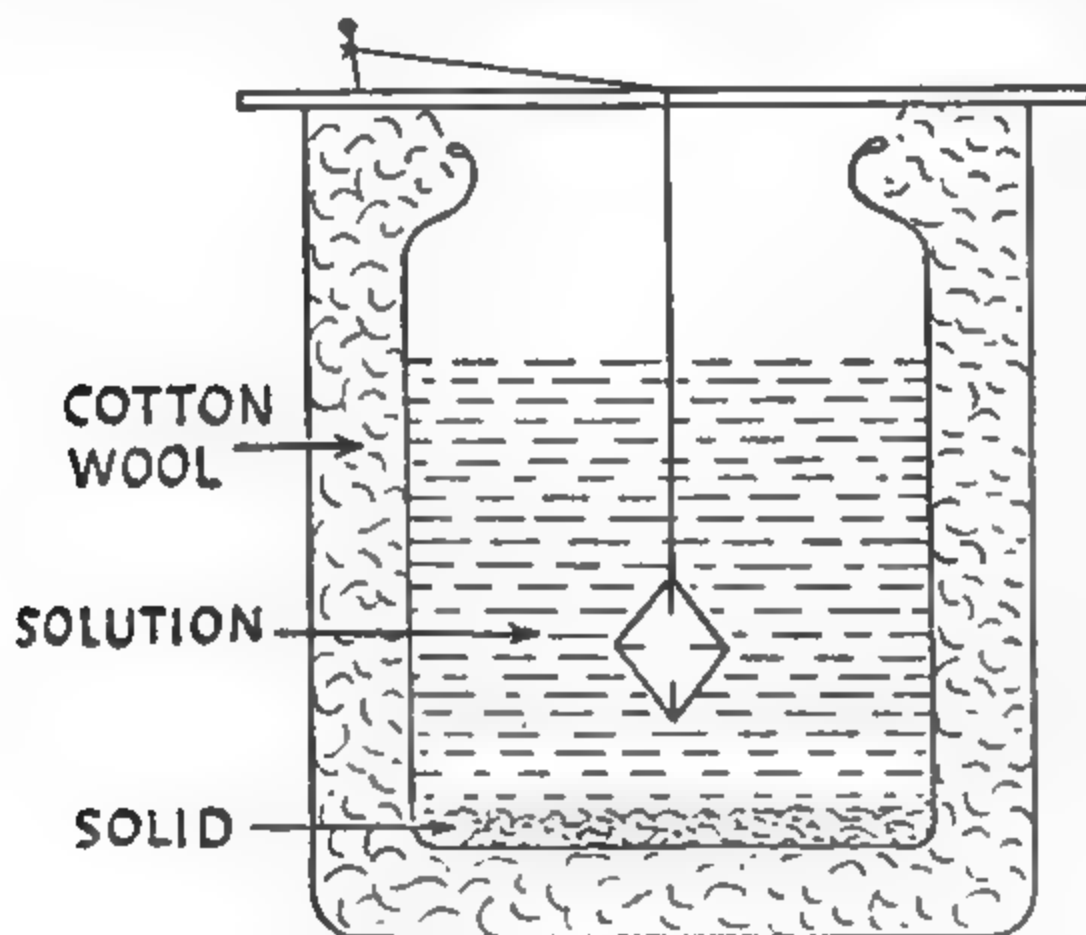


FIG. 46. METHOD OF GROWING A FERROUS SULPHATE CRYSTAL

spilled on clothes, so that care should be taken to prevent this happening.

### *A Ferrous Ammonium Sulphate Crystal*

Ferrous ammonium sulphate is a common chemical and can be bought cheaply. Alternatively, you can make some for yourself from ferrous sulphate and ammonium sulphate, as described at p. 60. It forms a beautiful crystal, which is transparent and light green in colour (Plate 5). It is an easy crystal to grow. The method used is similar to that described for the alum crystal. A little dilute sulphuric acid or sodium bisulphate solution should be included when the saturated solution is being made. Again care should be taken to avoid spilling the solution, which may cause iron mould.

### *A Copper Ammonium Sulphate Crystal*

This chemical is not very common, but it can easily be made from copper sulphate and ammonium sulphate, as described at p. 61.

The crystal, which is a beautiful light blue in colour, has the same general shape as a ferrous sulphate crystal (see Plate 5). It is one of the more difficult crystals to grow, but successful results can be obtained with the method of slow growing described for the ferrous ammonium sulphate crystal.

### *Preserving Crystals*

If you wish to make a permanent collection of the crystals which you have grown it is necessary in some cases to protect them from the air, because some crystals spoil on exposure to air. Chrome alum, copper sulphate, ferrous ammonium sulphate, and copper ammonium sulphate need no protection, as they are not affected by the air. Crystals of potash alum, iron alum, and ferrous sulphate all change when left in the air, although the reasons for the changes are not the same in every case.

Potash alum and iron alum are efflorescent—that is, the surface acquires a powdery layer, which ruins the appearance of the crystals. The same phenomenon has been noted with washing-soda crystals (p. 89). The change is brought about by loss of water of crystallization to the atmosphere. The tendency for the change to occur is only slight in the alums, and in winter, when there is plenty of moisture in the atmosphere, it may not happen at all. In dry summer weather it is certain to occur.

Ferrous sulphate crystals turn brown when exposed to the air, because the atmospheric oxygen oxidizes them to brown ferric sulphate.

Crystals of both alums and ferrous sulphate can be preserved by putting them in a bottle with a tightly fitting stopper or lid. Another method is to apply a transparent protective covering to the surface of the crystals. The best protective covering, in the author's experience, is Perspex cement, which is used for joining together pieces of Perspex (p. 221). This cement gives a hard, transparent coating which does not readily chip off. Another good material to use is colourless nail-varnish. Egg-shell varnish can be used, but tends to give a crystal a slightly yellowish appearance.

When you are applying the protective covering rest the crystal on top of an egg-cup and paint the top half of the crystal first. Allow the varnish to dry; then turn the crystal over and paint the other half. Two or three coatings of the material should be given.

Finally, do not handle your crystals, or allow other people to handle them, more than is absolutely necessary. There is always moisture on the fingers and repeated handling will damage the faces of the crystals and cause them to lose their lustre.

*The Structure of Crystals*

If, as a result of your experiments, you have become really interested in crystals you may be interested to know a little more about how they are built up. Although crystals sometimes appear to have a complicated shape, the fundamental plan of their structure is actually very simple. A builder who contemplates putting up a lot of houses in a road may not wish all his houses to look alike. He therefore makes out three or four different plans, so that he can build three or four types of house. In the same way, Nature has designed altogether seven plans for crystals, and these we call the seven crystal 'systems.' Only three of these systems are represented

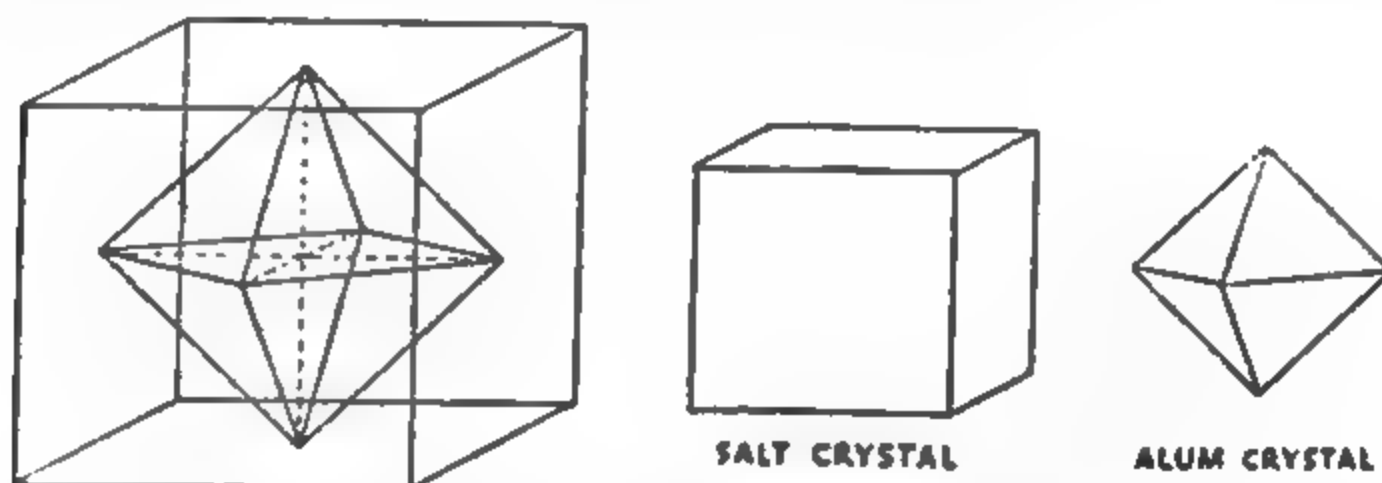


FIG. 47. WHY COMMON SALT AND ALUM BELONG TO THE SAME CRYSTAL SYSTEM

The axes of symmetry (dotted lines) are at right angles to each other and are of equal length.

by the crystals described in this chapter. We shall deal briefly with the three systems.

**The Cubic System.** Common salt, potash alum, iron alum, and chrome alum are included in this system.

We say that the earth spins on its axis once in twenty-four hours. The axis of the earth is an imaginary line running from the north pole to the south pole through the centre of the earth. Similarly, we imagine lines drawn through a cubic crystal of common salt to the centre of the faces as shown by the dotted lines in Fig. 47. These imaginary lines in the crystal are called axes of symmetry, and there are three of them.

It is obvious from Fig. 47(a) that any crystal which forms a cube must have its three axes of symmetry at right angles to each other and, furthermore, they must be equal in length. This is the fundamental plan of all crystals which fall within the cubic system.

The conditions that the three axes of symmetry should be at right angles to each other and of equal length are also fulfilled by an alum crystal. It follows that the same fundamental plan can give rise to a cubic crystal like salt or an octahedral crystal like alum. Actually, an octahedral crystal of alum is merely a cube from which all the

eight corners have been cut off. The cornering of crystals in this way is very common in practice and is quite in keeping with the fundamental plan of the crystal. This is shown by the fact that when salt is crystallized from solution under special conditions it forms

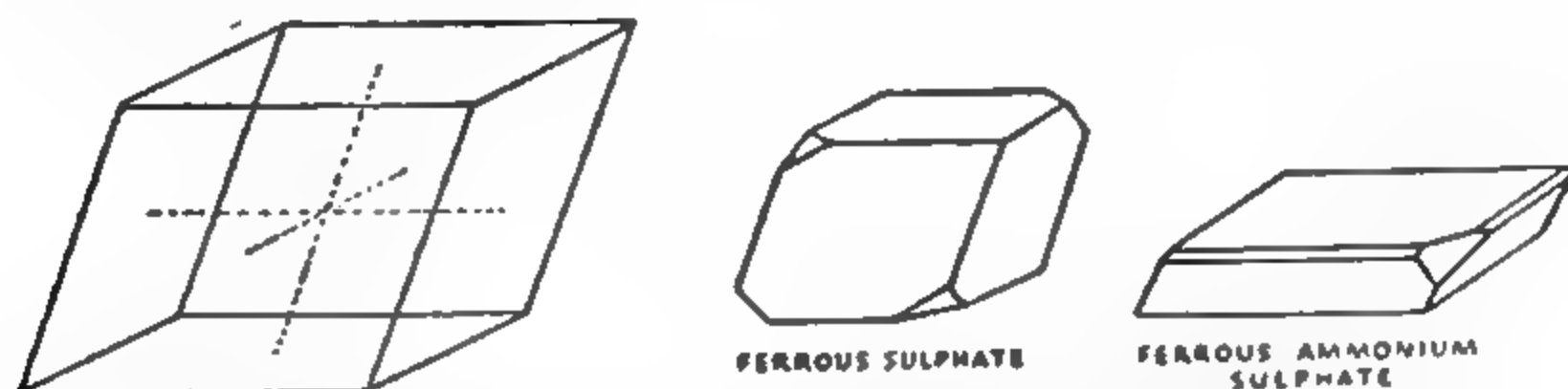


FIG. 48. WHY FERROUS SULPHATE AND FERROUS AMMONIUM SULPHATE BELONG TO THE SAME CRYSTAL SYSTEM

Two of the axes of symmetry (dotted lines) are at right angles to each other and the third is inclined to the other two. The lengths of the axes are unequal.

octahedral crystals like alum and not cubes. Clearly, whether the fundamental plan gives rise to a cubic crystal or an octahedral crystal depends on circumstances.

**The Monoclinic System.** This is the most common system of the crystal world, and to it belong the crystals of ferrous sulphate, ferrous ammonium sulphate, and copper ammonium sulphate. Other members are sugar, washing-soda, and Glauber's salt.

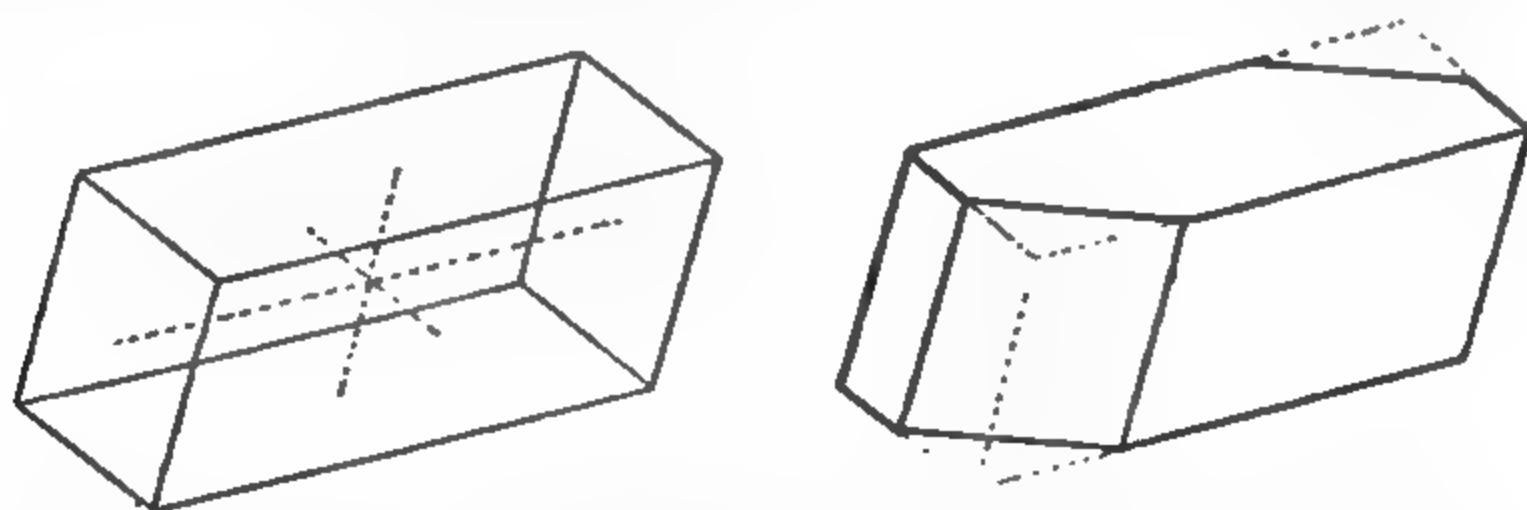


FIG. 49. HOW A COPPER SULPHATE CRYSTAL IS CONSTRUCTED  
The axes of symmetry are all inclined to each other and are unequal in length.

Again there are three axes of symmetry. This time, however, only two of them are at right angles to each other and the third is inclined to the other two. The bright reader will notice that this is indicated in the name 'monoclinic.' The lengths of the axes are all unequal. This is shown in Fig. 48.

Cornering is again common with crystals in the monoclinic system (as is illustrated by the ferrous sulphate crystal), but this does not disagree with the fundamental plan. Ferrous sulphate crystals have the chemical formula  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , while that of ferrous ammonium sulphate is  $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ . We see that



the only difference between the two substances is that one molecule of ammonium sulphate replaces one molecule of water of crystallization from ferrous sulphate crystals. It is reasonable, therefore, to expect that the two substances would crystallize according to the same plan.

**The Triclinic System.** In this system we find copper sulphate crystals. As the name 'triclinic' indicates all the three axes of symmetry are inclined to one another and do not form any right angles. In addition, all the axes are unequal in length. The usual shape of the copper sulphate crystal, which looks complicated, is simply the result of cornering. This is shown in Fig. 49.

## CHAPTER VIII

### *The Preparation and Collection of Gases*

THE preparation and collection of gases at home are more difficult than in a laboratory, where the proper apparatus is available. However, for the boy who wishes to acquire skill at fitting together and handling apparatus, these experiments provide splendid practice.

Only small-scale preparations are described, so that if you follow the instructions there is little risk of blowing yourself up, gassing yourself into insensibility, or otherwise giving cause for alarm to your parents. The preparation and collection of hydrogen are not included in this chapter. This gas is too dangerous for any but experienced chemists to experiment with. Even in laboratories it has been the cause of more serious explosions than all the other gases put together.

The apparatus described is of the simplest kind, and, apart from corks and glass tubing, consists mostly of materials found at home. As far as possible methods of preparation are given in which heating is not required. When heating cannot be avoided, it is a good idea to obtain the help of a friend for the preparation. One person can look after the heating while the other is giving his attention to the collection of the gas.

#### *Materials required*

The best kind of vessel to use for preparing gases is usually a small flask. A flat-bottomed flask is employed when heating is unnecessary, a round-bottomed flask when heating is required. In the former case a large medicine bottle can be used as a substitute for the flask, while a boiling-tube (p. 17) can often be used if heating is needed. A clamp for holding the vessel is a decided advantage, but it can be dispensed with if there are two people to carry out the preparation.

Rubber bungs are better than corks for fitting into a flask or bottle, as they are gas-tight. Rubber bungs can be bought already bored for the size of tubing usually employed in collecting gases (see p. 22), but ordinary corks can be made fairly gas-tight if they are first soaked in melted candle-wax. It will be necessary to bore the cork and pass a short right-angled piece of glass tubing through it. The reader should revise these operations as described at p. 29. The ends of the tubing should be rounded off in the edge of a flame (p. 31).

In addition to the right-angled piece of glass tubing one or two

other lengths are needed as delivery-tubes. A single length of ten or eleven inches can be made to suffice if a right-angled bend is made about two inches from one end, extra length being added to the tube when required by means of rubber tubing (Plate 6 illustrates

the use of this single delivery-tube in different methods of collection).

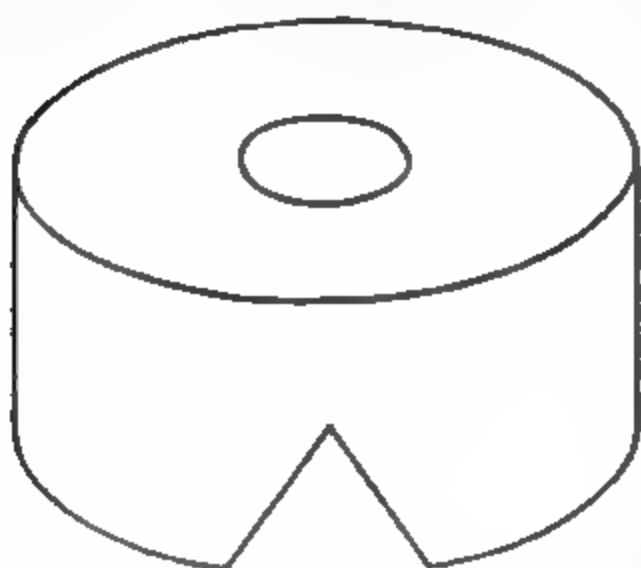


FIG. 50. A BEE-HIVE SHELF

off the bottom of a cylindrical cardboard salt-container with an old razor-blade or sharp knife. Make a circular hole, about half an inch in diameter, in the middle, and cut a V-shaped piece from the side, as shown in Fig. 50. If you paint the cardboard with melted wax it will withstand the action of the water for a long time. A bee-hive shelf can also be cut out of a tall, circular tobacco-tin.

For covering the open ends of the tumblers or jars, cut out squares of stiff cardboard, making them somewhat larger than the opening they have to cover. These squares take the place of the glass plates usually employed in laboratories for collecting gases. They will be more efficient if a thin layer of grease or melted wax is spread over one side.

A deflagrating-spoon is a useful aid in testing gases. This is a spoon used for introducing burning substances into a gas. You can make such a spoon from an old saltspoon or teaspoon. Bend the bowl of the spoon at right-angles to the handle and attach to it a length of stout copper wire, winding the wire round the handle, as shown in Fig. 51.



FIG. 51 A  
DEFLAGRATING-  
SPOON

### *Oxygen ( $O_2$ )*

There are usually two or three different methods of making any gas. When this is so, it is advisable to choose a method, if possible, which gives off the gas in a slow, steady stream rather than one which produces a large volume of the gas in a quick burst. You will then

have time to replace your collecting vessel with a fresh one when the first has been filled with gas.

There are two convenient methods of preparing oxygen from common chemicals so that a steady stream of gas is obtained:

(i) From hydrogen peroxide and a suitable catalyst (ferrous sulphate or manganese dioxide). No heating is required. The best strength for the hydrogen peroxide is '20 volume' (see p. 77). The ferrous sulphate should preferably be in the form of small crystals rather than powder. Manganese dioxide is contained in the black powder in old flashlight batteries (p. 196), and this powder can be used directly without purification.

(ii) From bleaching fluid or bleaching powder, with cobalt chloride as a catalyst. In this case heating is necessary.

For the first method of preparation set up the apparatus shown in Plate 6, using a flat-bottomed flask or large medicine bottle for the chemicals. Join the delivery-tube by a length of rubber tubing to the right-angled tube which passes through the cork. The lower end of the delivery-tube passes through the opening cut in the side of the bee-hive shelf. The water in the basin should be somewhat higher than the top of the bee-hive shelf.

First fill the tumbler (or jam-jar) completely with water and slide a cardboard disk over the top so that no air is trapped in the tumbler. Hold the cardboard on firmly with one hand and, grasping the tumbler in the other hand, turn it over and place it with the open end downward in the basin. Then slide away the cardboard. Do not put the tumbler on the bee-hive shelf until the preparation has been in progress for a minute or two. This will allow time for the oxygen to sweep the air out of the bottle and tubes.

Put about three egg-cupfuls of hydrogen peroxide solution into the bottle. Add a teaspoonful of ferrous sulphate crystals or manganese dioxide powder and replace the cork in the bottle. In a few seconds effervescence will begin, and bubbles of gas will be given off. Wait for a minute or two and then place the tumbler on the bee-hive shelf. The tumbler will be full of oxygen in two or three minutes.

When the tumbler has been filled with the gas slide the cardboard disk over the mouth again and remove the tumbler from the water. A second tumbler which has previously been got ready can now be placed in the basin. You should be able to fill about three tumblers with oxygen if you have used the quantities of chemicals specified. With these tumblers you can perform the tests which are shortly described.

To prepare oxygen from bleaching fluid, put three egg-cupfuls of the strong fluid into a flask or boiling-tube and add half an egg-cupful of fairly strong cobalt chloride solution. Instead of the

bleaching fluid, a tablespoonful of bleaching powder and a tablespoonful of water can be used. In both cases a black liquid will be formed. Heat the flask or boiling-tube over a small flame until a steady stream of gas is given off, and then remove the flame. Collect the gas as described previously.

The following tests can be carried out with the tumblers containing oxygen which you have prepared. They all illustrate the fact that oxygen is an extremely good supporter of combustion.

(i) Light a wood spill, blow it out, and introduce the still-glowing spill into the tumbler. The spill will relight immediately. If the spill is withdrawn at once when it relights and the cardboard cover replaced, there will be sufficient oxygen left in the tumbler for the next experiment also.



FIG. 52. METHOD OF BURNING STEEL-WOOL IN OXYGEN

(ii) Put a piece of candle-wax the size of a pea into a deflagrating-spoon (p. 170), set fire to the wax by heating the spoon, and lower the spoon into the tumbler. The wax will burn brilliantly. When the burning has stopped pour a little lime-water into the tumbler and shake it up. The lime-water will turn milky, showing that carbon dioxide is formed by the burning of the wax. The candle-wax consists largely of carbon.

(iii) Hold a small bunch of fine steel-wool in a pair of pliers, heat it for a couple of seconds (not longer) in a Bunsen flame, and quickly lower it into the gas. The steel wool will burn with a brilliant shower of sparks. Be careful not to touch the sides of the tumbler with the wool. It is advisable also to have a little sand or water at the bottom of the tumbler for this experiment, otherwise molten drops of iron may fall from the steel wool and crack the tumbler. The sand or water can be added quickly from a test-tube to the tumbler while the cover is removed for a moment.

(iv) Put some powdered charcoal on to a deflagrating-spoon and heat it strongly for a few seconds. When the charcoal begins to glow lower the spoon into a tumbler containing oxygen. The charcoal will burn fiercely, forming carbon dioxide. The latter can be tested with a few drops of lime-water, which will turn milky.

### *Carbon Dioxide (CO<sub>2</sub>)*

Carbon dioxide can be made without heating from effervescing health salts and water or by the action of an acid on chalk, baking-soda, or washing-soda. Sulphuric acid, sodium bisulphate, or alum

solution should not be used with chalk, as the chemical action quickly stops. Vinegar is too weak an acid to give much carbon dioxide. To obtain a steady stream of the gas either of the following combinations of chemicals is suitable:

- (i) Alum with baking-soda or washing-soda.
- (ii) Citric acid with chalk or washing-soda.

It will be sufficient if the preparation from alum and baking-soda is described.

Set up the apparatus shown in Plate 6. Put into the bottle (or flask) a tablespoonful of baking-soda (sodium bicarbonate) and an equal amount of powdered alum. The gas should be collected downward, or, as it is sometimes called, by 'upward displacement of air.' The delivery-tube should reach nearly to the bottom of the tumbler. To prevent draughts from blowing the gas away, cover the mouth of the tumbler with a square of wet or greased cardboard, leaving a hole in the middle for the delivery-tube to pass through.

When the apparatus is ready pour into the bottle just enough water to cover the chemicals, and replace the cork. Effervescence will begin immediately, due to the giving off of carbon dioxide. Wait for a few minutes and then test for the tumbler being full of carbon dioxide by raising the cardboard cover and putting a lighted taper or spill into the tumbler. If the tumbler is full the light will be extinguished at once. When this occurs lift the bottle and delivery-tube and slide a square of wet or greased cardboard over the top of the tumbler. Put the delivery-tube into a second tumbler and fill this with carbon dioxide in the same way.

With the quantities of chemicals given you should be able to fill three or four tumblers with carbon dioxide. If the chemical action becomes slow add a little more water to the bottle. This will speed up the action. You can carry out the following experiments with the gas collected.

(i) Test an empty tumbler with a lighted taper or wood spill to show that the flame is not extinguished. Now pour a tumblerful of carbon dioxide, just as if it were water, into the empty tumbler. If the latter is again tested with a lighted taper or spill the flame will be extinguished. The experiment is more interesting if a small lighted candle (the kind used on birthday cakes is suitable) is fixed to a piece of cardboard and placed at the bottom of the empty tumbler.

(ii) Add a little lime-water to a tumbler containing carbon dioxide and shake the liquid round. The lime-water will be turned milky.



(iii) Add a *few drops* of sodium hydroxide solution (keep the liquid off your fingers) to a tumblerful of the gas. Hold a square of wet or greased cardboard tightly over the mouth of the tumbler and shake the liquid round. The gas will dissolve so rapidly in the solution that a vacuum will be formed inside the tumbler, and the cardboard will stick firmly to the glass. Wash out the tumbler carefully.

(iv) Pass the gas from the delivery-tube of your apparatus into a little water in a test-tube for a few minutes and then test the water with a piece of blue litmus paper. The paper will turn a dull red, because some of the carbon dioxide will have dissolved in the water to form a weak acid, carbonic acid.

### *Hydrogen Sulphide ( $H_2S$ )*

Hydrogen sulphide, or sulphuretted hydrogen, is the well-known gas with the smell of bad eggs. It is poisonous in large quantities, and even in small quantities it should not be breathed for long or it will cause sickness and headache. It can, however, be made safely, in small quantities, providing that you have good ventilation. If you carry out the preparation, do so when the smell is not likely to annoy other members of the household, and have a window wide open to the outside air.

The gas is prepared by the action of an acid on ferrous sulphide. Dilute sulphuric acid or a solution of sodium bisulphate, citric acid, or alum can be used. The gas is usually collected over warm water (it is moderately soluble in cold water), but it is not absolutely necessary to have the water warm. The apparatus required for the preparation is similar to that used for the preparation of oxygen (Plate 6).

When the apparatus is ready put two teaspoonfuls of ferrous sulphide into the bottle or flask and pour in a test-tubeful of the acid solution. If citric acid or alum solution is used it is advisable to have it slightly warm, otherwise the action is slow. Collect two or three tumblers full of the gas in the same way as described for oxygen, covering the full tumblers with cardboard. Carry out the following tests on the gas.

(i) Slip a silver coin into a tumbler containing the gas. The coin will turn black, because the metal combines with the sulphur in the gas and forms black silver sulphide. Hydrogen sulphide derived from the burning of coal is usually present in the atmosphere of towns and cities and tarnishes silver ornaments for the same reason. The silver coin (or silver ornaments) can be made bright again by rubbing with a cloth dipped in 'hypo' solution, which dissolves the black silver sulphide.

(ii) Put into the gas a piece of filter-paper or blotting-paper which

has been dipped in copper sulphate solution. The paper will turn black, owing to the formation of black copper sulphide.

(iii) Remove the cardboard cover from a tumbler and apply a light to the gas. It will burn quietly with a blue flame, and a yellow deposit of sulphur will be formed on the sides of the tumbler.

(iv) In a test-tube put about an inch of cold water and a blue litmus paper. Reverse the delivery-tube so that the shorter arm is now connected to the right-angled tube which passes through the cork. Pass the gas into the water for a few seconds. The litmus paper will turn red, showing that some of the gas has dissolved to form an acid (called hydrosulphuric acid). If the liquid, which smells strongly of the gas, is shaken with a few small pieces of freshly warmed charcoal the smell will disappear. This illustrates the well-known deodorizing action of charcoal (p. 67).

### *Sulphur Dioxide ( $SO_2$ )*

This is another gas with a strong smell, which is usually described as pungent. The most convenient method of preparation is by the action of an acid on 'hypo' (sodium thiosulphate) crystals. Dilute sulphuric acid, sodium bisulphate solution, or a strong solution of citric acid can be used as the acid. Heating is required. The chemicals are placed in a flask or boiling-tube, which is then warmed or, alternatively, the acid solution is warmed first and then poured on to the 'hypo' crystals contained in a medicine bottle. The action takes place more rapidly if the crystals have been crushed to a powder. The sulphur dioxide is collected in the same manner as carbon dioxide (Plate 6).

Put two tablespoonfuls of 'hypo' into the flask or bottle and just cover the chemical with the acid solution. Collect the gas in *dry* tumblers, as it is very soluble in water. Test the tumbler by means of a lighted taper or spill, which will be extinguished when the tumbler is full of sulphur dioxide. Collect two or three tumblers full of the gas and apply the tests now described.

(i) Wet a piece of blue litmus paper and drop it into the gas. The paper will turn red because sulphur dioxide is an acidic gas.

(ii) Sulphur dioxide turns yellow sodium chromate paper green (p. 69).

(iii) Sulphur dioxide is well known for its ability to bleach many coloured materials. This property can be illustrated by means of a red flower, such as a rose, tulip, carnation, or sweet pea. Wet the flower thoroughly under the tap and leave it for a few minutes in a tumblerful of the gas covered with cardboard. The petals of the flower will turn white. Sulphur dioxide bleaches because it removes oxygen from the chemicals which compose the colouring matter of

the flower. If the bleached flower is placed in a solution of an oxidizing agent, the oxygen is restored to the petals and the colour returns. This can be shown by soaking the bleached flower for a few minutes in a dilute solution of hydrogen peroxide or bleaching fluid.

(iv) To show that sulphur dioxide dissolves readily in water, take a tumblerful of the gas covered with cardboard. Turn the tumbler upside down and, placing the mouth under some water in a basin, remove the cardboard. Shake the tumbler gently in the water.

The water will rise rapidly as the gas dissolves.

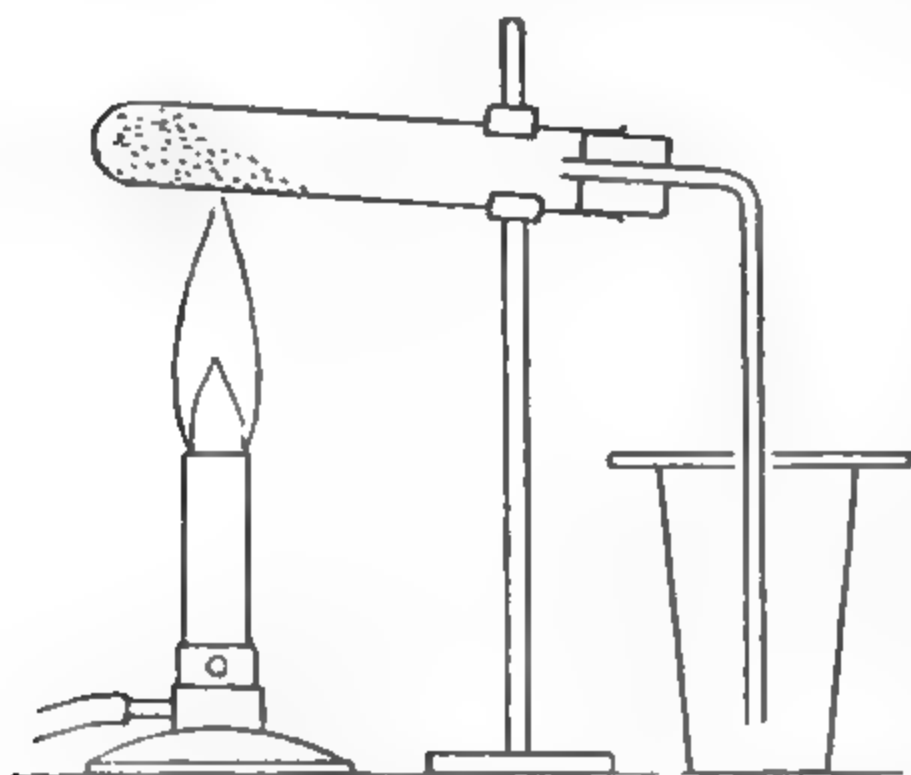


FIG. 53. APPARATUS USED TO PREPARE HYDROGEN CHLORIDE

### *Hydrogen Chloride (HCl)*

When pure and dry hydrogen chloride, or hydrochloric acid gas, is a colourless gas with a pungent smell, but in damp air it forms 'steamy' fumes. It can be prepared by heating a mixture of common salt with sodium bisulphate, ferrous sulphate or alum in a test-tube (a hard-glass tube is better). The apparatus required is shown in Fig. 53 (the clamp

can be dispensed with if there are two people to carry out the preparation).

Crush the crystals of sodium bisulphate or other chemical used and thoroughly mix a teaspoonful of the powder with an equal amount of salt. Put the mixture into a dry tube and clamp or hold the tube so that it slopes down slightly. This will prevent the moisture given off from running back on to the hot glass and cracking it. Collect the gas in a dry tumbler as shown.

Warm the tube over a small flame to start with, moving the flame about below the tube. Gradually make the flame hotter, but do not heat so strongly that the tube begins to melt. When the tumbler is full of hydrogen chloride a lighted taper or spill will be extinguished by the gas. Collect two tumblers full of the gas and use them for the following tests.

(i) Test the solubility of the gas in the same way as described for sulphur dioxide by turning a tumblerful of the gas upside down and putting the tumbler into water. Hydrogen chloride is one of the most soluble of the common gases, being second only to ammonia in this respect. The solution formed is weak hydrochloric acid.

(ii) Damp a small wad of cotton-wool with strong ammonia

solution. Drop the cotton-wool into a tumbler containing hydrogen chloride and quickly replace the cover. A thick white smoke will immediately fill the tumbler. The white fumes consist of sal-ammoniac (ammonium chloride) formed by the combination of the ammonia gas and the hydrogen chloride. This action is sometimes used to make artificial smoke on a big scale.

### Chlorine ( $\text{Cl}_2$ )

Chlorine is a green gas with an extremely choking smell. It is poisonous if breathed in large quantities, but you can safely prepare and collect small amounts of the gas. At the same time, however, you should take precautions against breathing too much of the gas, by having a window wide open. Any discomfort due to accidentally breathing the gas can be relieved by gently sniffing the fumes from a bottle of *dilute* ammonia and then doing some deep breathing in the open air.

Chlorine can be made easily, without using heat, by the action of dilute sulphuric acid, sodium bisulphate solution or citric acid solution on either chloride of lime (bleaching powder) or sodium hypochlorite solution (bleaching fluid).

The gas has a small solubility in water and is therefore usually collected downward (by upward displacement of air), as it is a heavy gas. The most convenient method, however, is to collect it over water—in spite of its small solubility—so that the gas does not escape into the room. The apparatus employed for the preparation and collection of oxygen is suitable (Plate 6).

Put five or six teaspoonfuls of chloride of lime or an egg-cupful of strong bleaching fluid into the bottle. Add an egg-cupful of the acid solution. Have other tumblers ready to take the place of the first tumbler when it has been filled with the gas. Cover each tumbler with cardboard when it is full and remove the tumbler from the water. Fill three tumblers with chlorine and use them to carry out the following tests.

(i) Hold a sheet of white paper behind a tumbler and notice the green colour of the gas.

(ii) Drop a piece of damp litmus paper, red or blue, into the gas. The paper will be quickly bleached. This is the usual chemical test for chlorine.

(iii) Write your name in ink on a piece of paper. Drop the paper into the tumbler and cover the tumbler immediately. The writing will disappear, because the chlorine bleaches the ink.

Write your name on another piece of paper, but this time blot the ink and dry it by holding the paper over a small flame or near the fire. Drop the paper into the gas. The writing will be bleached

only slowly if at all. Chlorine does not bleach in the absence of moisture, but, since the gas has been collected over water, it will be slightly damp.

(iv) Light a taper or set fire to a little candle-wax in a deflagrating-spoon. Put the burning taper or wax into a tumbler containing chlorine. The flame will continue to burn with a dull red colour

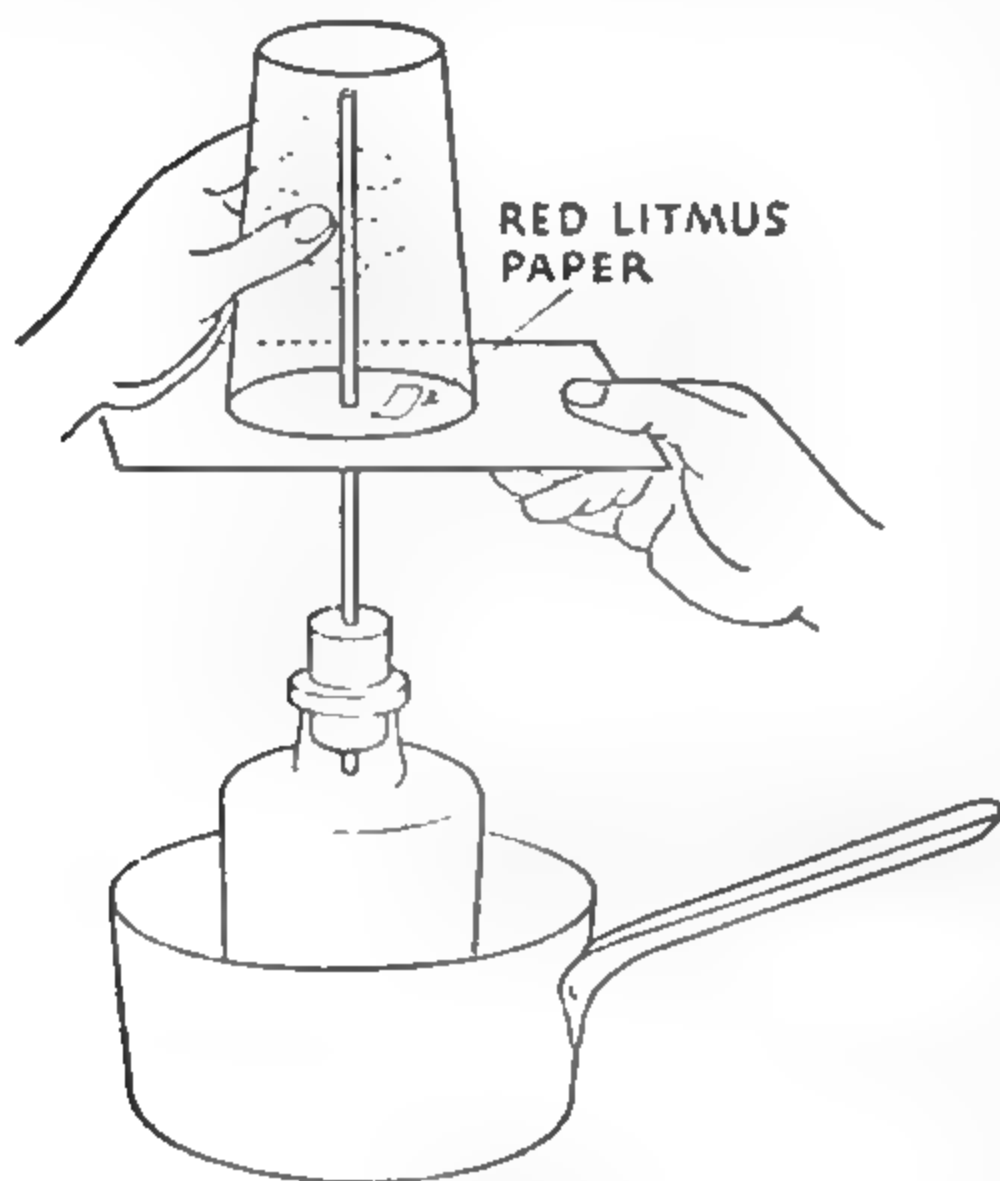


FIG. 54. APPARATUS USED TO PREPARE AMMONIA GAS

and a cloud of grey smoke will be formed. The smoke is a mixture of black carbon particles and white steamy fumes of hydrogen chloride. Test for the presence of the latter by removing the stopper from a bottle of strong ammonia and placing the open end near the top of the tumbler. Thick white fumes will be formed (see the ammonia test for hydrogen chloride, p. 176).

(v) Into the third tumbler full of chlorine put a tea-spoonful of slaked lime. Holding the cardboard cover on, shake the powder in the tumbler. The green colour of the chlorine will disappear, because the gas is absorbed by the slaked lime. The sub-

stance formed in this chemical action is chloride of lime, or bleaching powder (p. 61).

### *Ammonia ( $NH_3$ )*

Ammonia is another colourless, or invisible, gas. The 'liquid ammonia' sold in shops for cleaning is a strong solution of the gas in water. The pungent smell observed when the stopper is removed from the bottle shows how readily the gas escapes from the solution.

Ammonia gas is given off when any ammonium compound, such as ammonium chloride, is warmed with any alkali, such as caustic soda, washing-soda or lime-water. The easiest method of obtaining the gas, however, is simply by warming the strong solution of household ammonia. As the gas is lighter than air, it has to be collected upward (or by downward displacement of air).

Put an egg-cupful of strong household ammonia into a medicine bottle (or small flat-bottomed flask). Through the cork of the bottle

insert a straight length of glass tubing eight or nine inches long and pass it through a square of dry cardboard with a hole in the middle. Heat a little water in a saucepan until the water is just too hot to bear the hand in comfortably. Place the saucepan on your bench and stand the bottle containing the ammonia solution in it. Lower a *dry* tumbler mouth downward over the glass tube so that the end of the tube is at the top of the tumbler. Hold the cardboard with the other hand so that the mouth of the tumbler is covered (Fig. 54). It is a good idea to have a piece of damp red litmus paper resting on top of the cardboard in the tumbler, so that you can tell by the turning blue of the paper when the gas is being given off.

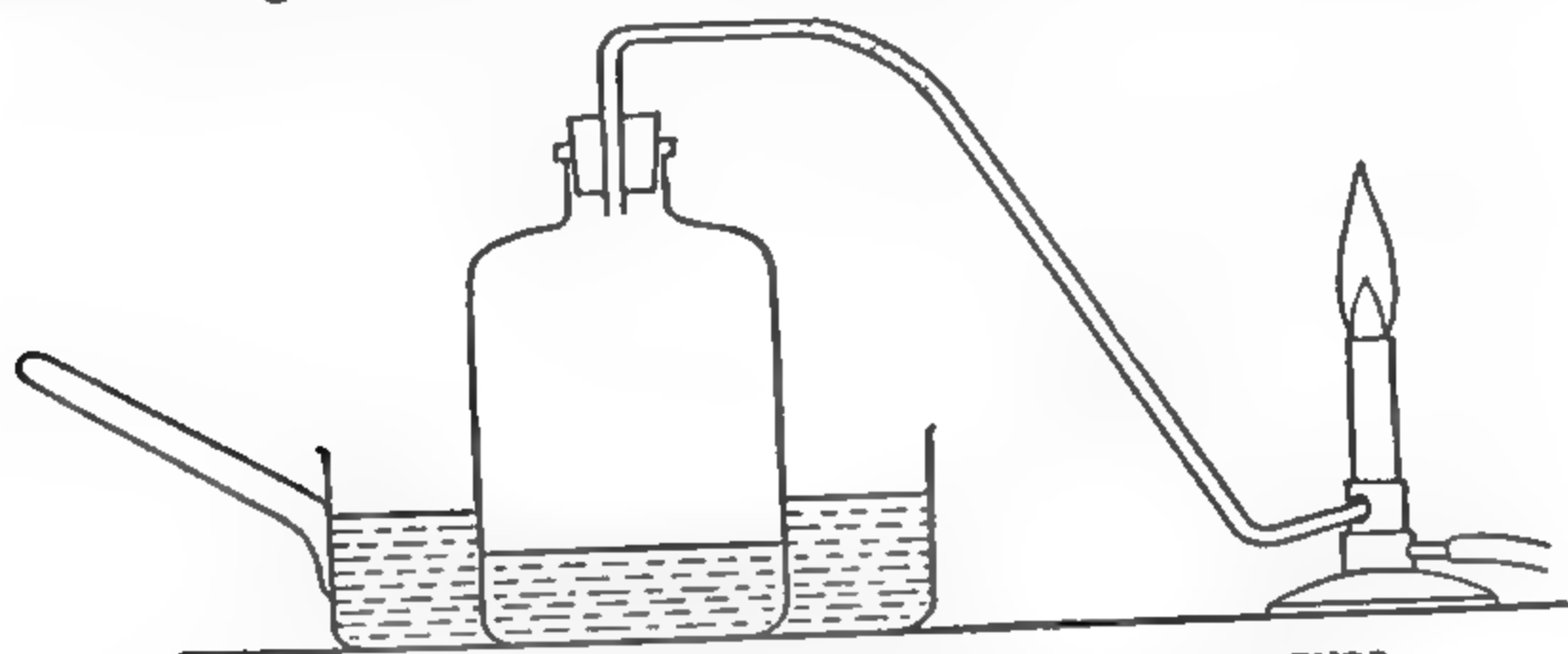


FIG. 55. BURNING AMMONIA AND COAL-GAS TOGETHER

Do not remove the tumbler immediately when the litmus paper turns blue. Leave it for about half a minute longer. Then raise the tumbler, still keeping the mouth covered with the cardboard. Keep the mouth of the tumbler downward and, after removing the bottle from the saucepan, carry out the following test on the solubility of the gas.

(i) Place the tumbler mouth downward in a basin of water and slide away the cardboard cover. Shake the tumbler gently in the water. The water will rise quickly inside the tumbler as the gas dissolves. Ammonia is the most soluble of all gases in water, which explains why a lot of the gas can be obtained from quite a small amount of the strong solution.

If you wish to collect a second tumblerful of ammonia you will have to use a fresh, dry tumbler and another piece of dry cardboard.

(ii) Ammonia gas does not burn when a light is applied to it, but by slightly altering the apparatus used for the preparation the gas can be made to burn, as illustrated in Fig. 55.

Change the straight glass tube which passes through the cork of the bottle to a right-angled tube, and connect your right-angled delivery-tube to this by rubber tubing. Place the bottle containing



the strong ammonia solution in the saucepan of hot water as before. Hold the end of the delivery-tube to the air-hole of a Bunsen burner which has a small flame (the air-hole should be partly open). When the ammonia gas is given off it will mix and burn with the coal-gas. The size of the flame will increase considerably and will change to a peculiar yellow colour.

(iii) Another way of demonstrating the great solubility of ammonia gas is by means of the Fountain Experiment (p. 143). To carry out the experiment, put only a few drops of the strong household ammonia into the flask (fitted up as described at p. 143) and warm the latter *gently* for a few seconds. Then turn the flask and tube upside down and put the end of the tube into some water in a basin. The water will rush up into the flask in fine style and produce a splendid fountain.

The experiment can be made even more striking by adding a few drops of phenolphthalein to the water in the basin. The water will then become red in colour when it enters the flask.

## CHAPTER IX

### *Chemical Magic*

THIS chapter is concerned with Chemistry as an entertainment. You can amuse either yourself or your friends by means of the experiments described. At parties you are certain to be the success of the evening if you can put on a show of interesting or spectacular experiments, particularly if there is an element of mystery or magic in some of them.

The best experiments to choose are those which are easy to perform and require the minimum of apparatus. For the benefit of readers who contemplate the staging of an entertainment, a few words of general advice might not be out of place.

1. Do not despise very simple experiments, especially if the audience is young. To those who have never seen it done before the relighting of a wood spill by oxygen is quite an unexpected and mysterious occurrence.

2. Rehearse each experiment two or three times under the conditions which you will have to use. Only in this way can you discover the snags which are likely to crop up.

3. Do not attempt too many experiments. Half a dozen experiments successfully carried out will create a bigger impression than twice the number badly done.

4. When once you have finished an experiment successfully do not repeat it, in spite of the many requests you will probably get to do it again.

5. Do not explain to your audience how an experiment works. They will enjoy it more if they are left in a state of bewilderment.

6. Before you start an experiment state clearly what you intend to do. If you can talk or 'patter' while the experiment is in progress the audience will be more interested than if you carry out the experiment in dead silence.

Among the simple experiments which have been described earlier in this book and which are suitable for an exhibition of chemical magic are the following:

Invisible inks (p. 39).

Relighting of a glowing spill by oxygen made from hydrogen peroxide and manganese dioxide or ferrous sulphate (p. 50).

The 'pop' of hydrogen (p. 50). In this and the previous experiment allow a young member of the audience to apply the test.

Coloured flames (p. 47). These can be demonstrated with a candle-flame or spirit-burner.

A chemical garden (p. 96).

Luminous pebbles (p. 146).

Camphor burning on water (p. 150).

Freezing water without ice or snow (p. 146).

Getting a quart into a pint pot (p. 147).

Some of these experiments will be more spectacular if they are performed in a darkened room, which also helps to create an atmosphere of mystery.

### *Invisible Writing*

Many invisible-ink tricks depend on writing with one chemical on paper beforehand and then developing the writing by means of a second chemical. The trick is more impressive if you can make it appear that you are using only water to do the writing. The following is a simple but effective way of demonstrating invisible writing.

Before the 'show' paint over one side of a sheet of drawing-paper with a very weak solution of copper sulphate and allow the paper to dry. The paper should then have only a slight bluish colour. If the colour is very noticeable (through using too strong a solution) it can be disguised by rubbing a little chalk lightly over the paper. Fasten the paper to a board with drawing-pins. If you dip a small brush into a weak solution of ammonia you can write or draw anything you wish on the prepared paper. The colour of the writing will be blue.

Another way of doing the trick is to paint some writing on the paper with a weak solution of the copper sulphate and after drying the writing disguise it by rubbing chalk lightly over all the paper. The writing will appear when the weak solution of ammonia is painted over it.

### *Appearing and Disappearing Writing*

Other chemicals which can be used for invisible writing are boiled starch solution and weak iodine solution. These give blue-black writing. When you are making arrangements beforehand, treat a sheet of drawing-paper with the boiled starch solution (for the preparation of this solution see p. 42). Write on the sheet, in view of your audience, with weak iodine solution. Two or three drops of tincture of iodine to an egg-cupful of water gives a solution which is quite strong enough for the purpose. It is a good idea to have the two or three drops of tincture of iodine at the bottom of a dark-coloured bottle, which can be shown as an 'empty' bottle. You can then ask a member of your audience to go out and put

some water into the bottle from the tap. Shake the bottle before using the liquid.

You can make the writing from starch and iodine disappear by means of sodium thiosulphate ('hypo') solution. An effective way of demonstrating this is to soak a piece of blotting-paper in a fairly strong solution of the 'hypo' and then press the blotting-paper on the writing. When you remove the blotting-paper the writing will have vanished.

### *Changing 'Water' to 'Ink' and back to 'Water'*

In this and the next two experiments, in which the colours of liquids are changed, small amounts of chemicals in solution are put beforehand at the bottom of glass tumblers or jam-jars. If only two or three drops of the solutions are used the tumblers or jars will appear to be quite empty. In no case, of course, should the liquids which you make be tested by tasting, as some of them are poisonous.

For this experiment you will require a jug and three tumblers. Prepare the tumblers by putting a few drops of freshly made boiled starch solution into the first, two or three drops of very weak iodine solution into the second, and a few drops of strong 'hypo' solution into the third.

Fill the jug with water (a member of the audience can do this). Pour water into the first tumbler. It will still look like water. Pour the water from the first tumbler into the second. The liquid will appear like ink. Finally pour the inky liquid from the second tumbler into the third. The colour will disappear and 'water' will again be formed.

### *'Water' to 'Wine' to 'Water'*

This experiment is carried out with the same apparatus and in a similar manner to the one just described. The chemicals used, however, are different. Prepare the tumblers or jars by adding to them a few drops of the chemicals mentioned:

Jar 1—weak sodium carbonate solution.

Jar 2—phenolphthalein solution.

Jar 3—dilute sulphuric acid or sodium bisulphate solution.

### *'Water' to 'Ink,' 'Lemonade,' and 'Wine'*

This is a more ambitious experiment, and needs a little more rehearsing, but it never fails to impress an audience. You will require a large jug, four tumblers or jars, and the following chemicals: tannic acid, iron alum or other ferric salt, citric or tartaric acid, and dilute ammonia. A small amount of tannic acid can be bought cheaply at the chemist's or you can make a solution by cutting

up some oak-galls and boiling the pieces with water (p. 113). The quantities of chemicals used need observing carefully.

Make a strong (preferably saturated) solution of the tannic acid and put a teaspoonful of the solution at the bottom of the jug. Prepare the four tumblers or jars as follows:

Jar 1—leave empty.

Jar 2—two or three drops of iron alum solution.

Jar 3—a teaspoonful of saturated citric or tartaric acid solution.

Jar 4—a teaspoonful of dilute ammonia.

To carry out the trick, fill up the jug containing the tannic acid with water. Use this to fill up the first jar. The liquid will look like water. Empty the jar back into the jug.

Fill up the first two jars from the jug. The first will still appear to contain water, but in the second the liquid will look like ink. Empty both back into the jug.

Fill up the first three jars. The liquid will appear inky in the first two and like lemonade in the third. Empty all three back into the jug.

Fill all four jars from the jug. The first three will look like lemonade and the fourth like port-wine. Pour all the jars back into the jug.

Finally fill all the four jars again from the jug. The liquid in each will now look like port-wine.

Perform the experiment smoothly and quickly. This is one item in your display in which you might remain silent when once you have begun the manipulating, as the audience is too intent on watching the colour changes to bother about the performer's patter.

The trick can well end with the transformation of the liquid into 'wine.' You should be prepared, however, for a challenge from somebody in your audience to change the 'wine' back into water. To meet this challenge, have ready another jug half full of water to which an egg-cupful of dilute sulphuric acid or sodium bisulphate solution has been added. Taking up one of the jars containing 'wine,' pour it into this jug and immediately refill the jar with liquid from the jug. The liquid will now look like water. Actually it will be slightly yellow in colour, but this will scarcely be noticeable.

### *A Burning Match Trick*

Nearly fill a shallow saucer with water and place a small coin on the side of the saucer underneath the water. Offer to give the coin to any member of the audience who can take it out of the saucer with his fingers, but without putting his fingers into the water or pouring the water away.

When the audience has given up the problem produce a tumbler and half of a small potato into which two matches have been inserted so that the heads lie close together. Put the piece of potato into the saucer. Strike a match, set fire to the two match-heads, and immediately place the tumbler in the saucer over the burning matches (Fig. 56). Almost at once the water in the saucer will rush up into the tumbler, leaving the rest of the saucer empty. You can now pick up the coin with your fingers.

The explanation of this trick is partly that the burning matches use up the oxygen gas in the tumbler and partly that the remaining nitrogen contracts as it cools. Both happenings cause the water to rise into the tumbler.

### *Reading Writing through an Envelope*

Ask a member of the audience to write a number of, say, three figures on a piece of paper without telling you what the number is. Now hand the writer a plain envelope and ask him to place the paper in the envelope with the writing to the address side and to seal it up. The envelope is handed to you. Producing a bottle of 'magic liquid' and a wad of cotton-wool, dab a little of the liquid on to the address side of the envelope. Now proceed to read out the number which was written on the paper.

This trick is quite straightforward. The liquid is methylated spirit. When this is dabbed on to the envelope it makes the paper transparent, so that the number inside can be read easily.

### *Magic Paraffin*

This is a liquid which will burn itself but will not set fire to paper, cloth, or other materials which usually burn. The trick can be shown well with a roll of ordinary bandaging.

First cut a length nine or ten inches long from the roll, insert a steel knitting-needle or fork through one end, and set fire to the bandaging over a plate. This is to demonstrate that it is ordinary bandaging, which has not been prepared in any way.

Cut another length of the material. Pouring some of the 'magic paraffin' into an egg-cup, soak the bandaging in the liquid and squeeze it out. Again holding the material with the knitting-needle or fork, set fire to it over the plate. The liquid on the bandaging will burn but the bandaging itself will not.

The secret of this mystifying trick is in the preparation of the

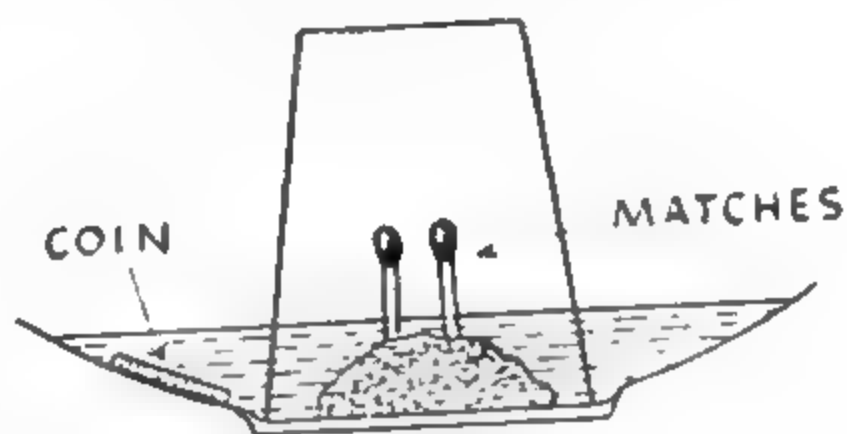


FIG. 56. APPARATUS USED FOR THE TRICK WITH BURNING MATCHES



'magic paraffin.' This is made by simply mixing together equal amounts of methylated spirit and water. While the mixture will burn itself, the water present prevents material soaked with it from setting on fire.

To vary the trick you can borrow a handkerchief from a member

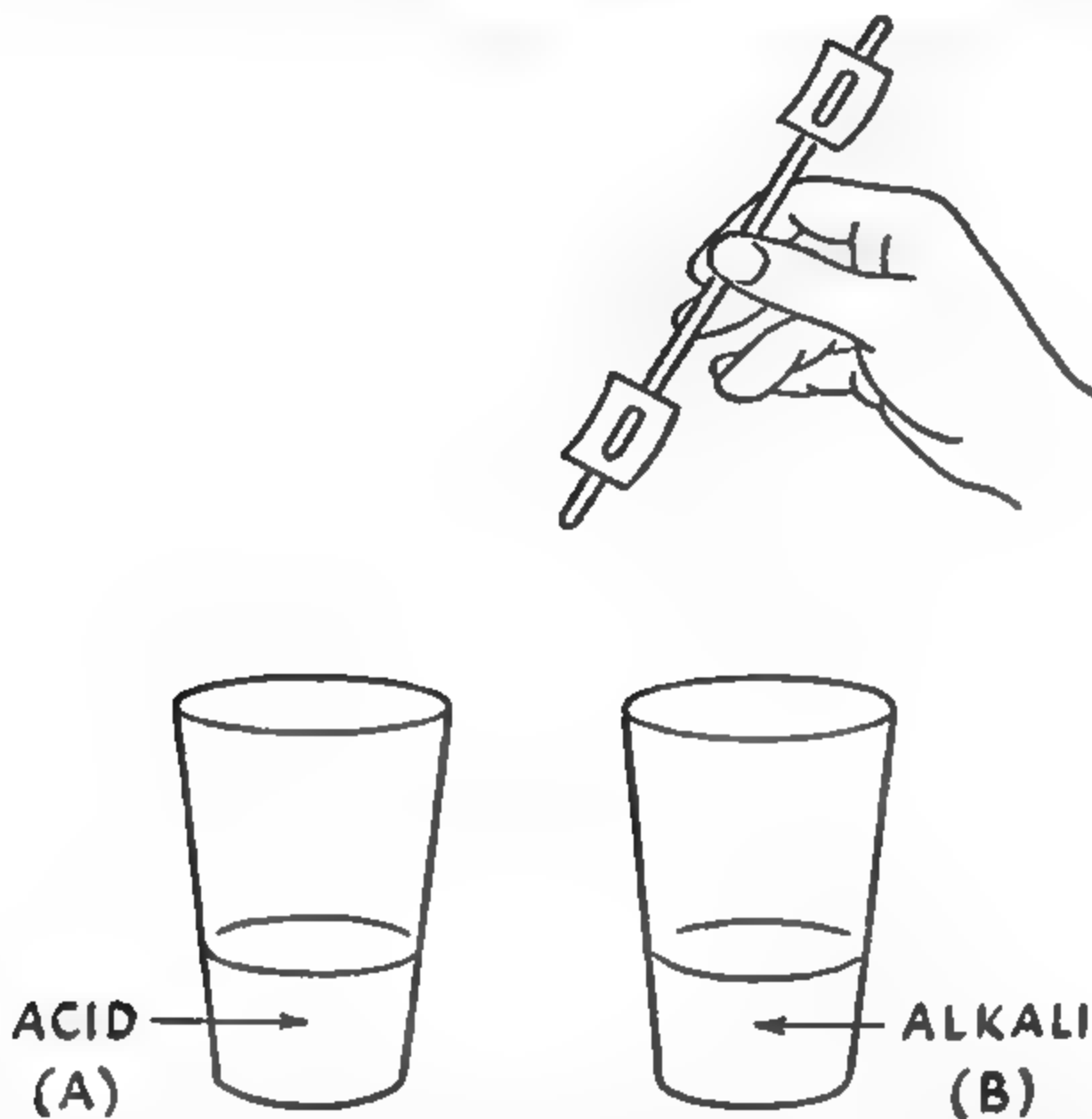


FIG. 57. CHANGING THE COLOUR OF BUS OR TRAM TICKETS

of the audience and use this instead of the bandaging to show the peculiarity of the liquid.

#### *Changing the Colour of Bus or Tram Tickets*

Two bus or tram tickets, one white and the other red, are shown to the audience. For convenience in handling it is a good plan to push a knitting-needle through small holes at the top and bottom of the tickets so that there is a ticket at each end of the needle (Fig. 57). The needle can be held in the middle.

Remarking that you have discovered how to turn a penny ticket into a twopenny one, you dip the red ticket into a tumbler containing a colourless liquid (call it liquid A). The ticket comes out blue.

Turning the needle over, you dip the white ticket into a second tumbler containing a colourless liquid (call it liquid B). The white ticket turns red.

Pointing out to your audience that this trick may lead to trouble

with the ticket-inspector, you proceed to change the tickets back to their original colours. This is simply done by dipping the ticket which is now red into liquid A and the ticket which is now blue into liquid B.

The tickets are prepared beforehand. Obtain two white tickets. If you cannot secure two white ones, convert two red ones into white ones by soaking them for a few hours in a weak solution of bleaching fluid, afterwards rinsing them in water. Dip one white ticket in a weak solution of Congo red and the other in colourless phenolphthalein solution. Dry the tickets in a warm place. You will now have one red and one white.

Liquid A is water to which a few drops of dilute sulphuric acid or sodium bisulphate solution have been added. Liquid B is dilute ammonia or washing-soda solution. Congo red turns blue in the acid solution but back to red in the alkali. Phenolphthalein turns red in the alkali but loses its colour again in the acid.

### *Revealing a Hidden Name*

Nine or ten pieces of paper are handed out among the audience for inspection. Each piece has a boy's name or a girl's name printed on it—Tom, Jim, Mary, etc. When the audience has had a chance of looking at the papers collect them up and put them into the pocket of your coat. Now request a member of the audience to step up, put his hand into your pocket, and take out any paper he chooses. The name on the paper is shown to the audience but not to you.

Ask the assistant to screw up the paper and hand it back to you. Apply a light to the paper and burn it on a saucer. Taking off your coat and rolling up your sleeves, dip a finger into the black ash on the saucer and rub the ash over your arm. The chosen name will appear in black writing on your arm.

This seemingly impossible trick is performed as follows. In the pocket of your coat (an old one is worn specially for the occasion) place beforehand nine or ten pieces of paper similar to the ones shown to the audience. All these papers, however, have the same name printed on them. The name should preferably be short—say, "Tom." A slit has been cut across the top of your coat pocket on the side near your body. When you put into your pocket the papers which have been exhibited slip them through the slit into the lining of your coat. When the assistant inserts his hand into your pocket he is bound to take out a paper with "Tom" written on it. Hold your hand over the slit while the paper is being selected.

The developing of the name on your arm is a simple matter. Before the show you have printed the name "Tom" on your arm

with sugar solution by means of a paint brush (wash your arm in soapy water before doing this). Let the writing dry on your arm. When the ash from the burned paper is rubbed over the writing the name stands out boldly in black letters.

Instead of writing the name on your arm, you can write it on a sheet of drawing-paper or cardboard. It will be invisible until the ash from the paper is rubbed over it.

### *The Magic Moth-ball*

This is an amusing trick, but there is nothing magical about it. Put a teaspoonful of sodium bicarbonate (baking-soda) and another of citric or tartaric acid into a tumbler, or use two teaspoonfuls of effervescing health salts. Nearly fill the tumbler with water, and when the liquid starts to effervesce put a moth-ball into it. The moth-ball will sink to the bottom of the liquid but will soon rise to the top, then sink to the bottom, and so on.

The curious behaviour of the moth-ball is caused by bubbles of carbon dioxide gas collecting on the moth-ball at the bottom of the tumbler. The bubbles act like small balloons and carry the moth-ball to the surface. Here the bubbles are released into the air and the weight of the moth-ball makes it return to the bottom.

### *The Candle that cannot be lit*

The following trick illustrates the old maxim that the simplest deceptions are often the most puzzling.

A small piece of candle is attached to a flat cork or lid and placed at the bottom of a tumbler. The latter is stood on your table and covered with a piece of cardboard. Drawing the attention of your audience to the candle, you offer a small prize to anybody who can remove the cardboard and light the candle with a taper or spill without touching the tumbler. Several of your audience are sure to want to try this apparently easy task. They will all fail, because as soon as the lighted taper or spill is put into the tumbler it goes out.

When three or four people have attempted to light the candle without success, you show how it can be done. Taking a length of glass tubing or a drinking-straw, you place it at the bottom of the tumbler and blow through it for a few seconds. You then light the candle quite easily with the taper or spill.

The secret of the trick is that the tumbler has previously been filled with carbon dioxide gas by adding effervescing health salts to a little water in the tumbler. A piece of greased cardboard ensures that the gas does not escape. When a lighted taper is put into the tumbler it is immediately extinguished by the gas. When you blow through the glass tubing or straw (with the lower end at

the bottom of the tumbler) the carbon dioxide is replaced by air. Then the candle can be lit.

### *The Blushing Doll*

This item of your entertainment requires a fair amount of preparation, but this is amply justified by the amusement which is created.

A rag doll (we will call her Betty) is shown to the audience with the announcement that Betty is like other dolls except that she is extremely shy. When she is kissed she blushes, but only if the kissing is done by a boy.

This is demonstrated by first asking a girl to come forward and kiss the doll. Betty's face is quite unaffected. A boy volunteer is called for. When he kisses the doll her face immediately turns a rosy pink colour.

Remarking that you cannot have Betty going about with a permanent blush, you proceed to dab her face with a wad of cotton-wool dipped in some 'water' in a cup. The blush disappears, and Betty's face looks normal again. If, however, a second boy volunteer comes forward and kisses the doll her face turns crimson once more.

For this demonstration you require an old rag doll. If you cannot make use of one which has been discarded by your sister it is not difficult to make one from cotton-wool and some pieces of an old sheet or pillow.

The head and body of the doll are prepared as follows. Make a wire frame for the front part of the head. It is easy to bend the wire frame of an old lampshade into the desired shape (see Fig. 58 (a)). Pack the back of the head with cotton-wool. In the body conceal a rubber bulb which is connected to a short glass tube. The latter projects into the lower part of the wire frame. Pad round the bulb with cotton-wool. Sew or pin up the cloth at the back of the doll, but leave the cloth open and overlapping at the back of the neck. This enables you to get at the glass tube and rubber bulb. Enlist the aid of a sister or girl friend to fit the doll out with a dress.

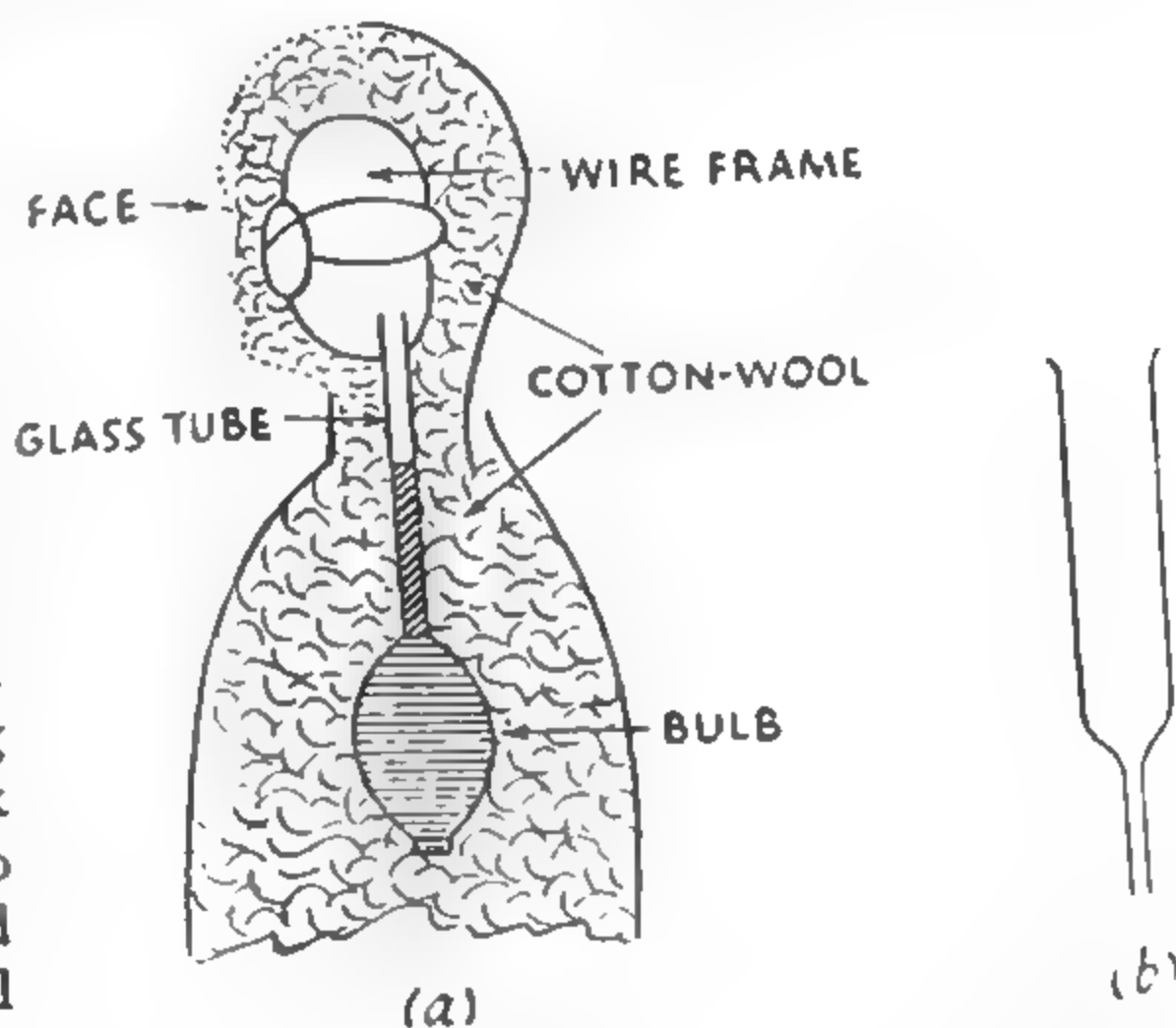


FIG. 58. (a) THE INTERNAL MAKE-UP OF THE BLUSHING DOLL; (b) THE SMALL GLASS FUNNEL

Before the show run a few drops of strong ammonia solution down into the rubber bulb. This can easily be done if you make a special funnel by heating a test-tube in the middle to soften the glass, drawing it out, and cutting it at the narrow part. A narrow tube is left attached to the top part of the test-tube (Fig. 58 (b) ). Insert the narrow tube into the neck of the rubber bulb, and after the ammonia has been poured in replace the short glass tube and make sure that the upper end is inside the wire frame.

On the face of the doll dab phenolphthalein solution. You can do this either just before you begin your performance or during it if you pretend that the doll's face is dirty. When you are carrying out the demonstration of the doll's peculiarity hold it round the body under the dress. When you want the doll to blush it is only necessary to squeeze the body once or twice. Ammonia gas will be given out from the rubber bulb over the face of the doll and the phenolphthalein will turn red. Of course, the bulb is only squeezed when a boy, and not a girl, kisses the doll.

To remove the 'blush' from the face, dab the latter with a dilute solution of citric or tartaric acid. This is the 'water' in the cup referred to earlier. Actually, the colour fades in the air alone after two or three minutes, but it is better to use the solution, rather than hold up the entertainment while waiting for the 'blush' to disappear.

### *A Spectacular Experiment*

The action of heat on ammonium dichromate is very impressive. This chemical consists of reddish-orange crystals, one ounce of which will suffice for your requirements.

When the crystals are heated in a dry test-tube (the heat from a spirit-burner is quite sufficient) they decompose with a brilliant shower of sparks, and a mass of green particles shoots out from the tube. The green substance is called chromium sesquioxide. Its volume is much greater than that of the original ammonium dichromate, and it is difficult for spectators to believe that so much matter can come from so little.

To carry out the experiment, put not more than half an inch of ammonium dichromate (which should be powdered) into a dry test-tube. Arrange a newspaper below the mouth of the test-tube to catch the green powder, which may be thrown out of the tube to a distance of two feet. Hold the tube in a paper-holder and heat it over the burner. There is no danger of an explosion, so do not drop the tube in alarm when the chemical action starts. The younger members of your audience particularly will be delighted by this experiment.

*Chemical Specialities*

There are several striking demonstrations which depend on special materials which you cannot make yourself but which you can often buy from shops dealing in chemical magic.<sup>1</sup> As these items provide excellent entertainment, they are well worth including in your performance. Three of the best-known will be described.

**Flash-paper.** Flash-paper looks like typewriting paper. Its peculiarity is that it burns up extremely quickly and leaves no ash at all. It costs a shilling for a sheet about ten inches square. This paper can be used as the basis of a trick, in the following manner.

Obtain a sheet of typewriting paper as similar in appearance as possible to the flash-paper. Cut the two pieces of paper to the same size beforehand. Show the papers to the audience, pointing out that they are quite ordinary pieces of paper. Fold the typewriting paper and set fire to it over a plate. Draw the attention of the audience to the ash which remains when the paper has burned.

Remarking that chemists have recently discovered a new substance which makes paper burn without leaving any ash, exhibit a small bottle containing a white powder. This can be powdered starch or any similar harmless substance. It is merely to aid you in persuading your audience that you are using ordinary paper, and it makes no difference to the burning of the flash-paper. Sprinkling a little of the powder on the flash-paper, rub it lightly over the surface and shake off any which remains. Fold the paper, hold it over the plate, and apply a light to it. The paper will burn up rapidly without leaving a trace of ash.

A more impressive finish to the trick is to hold the burning flash-paper in your hand and when about two-thirds of it has burned away to throw the remaining portion up into the air. The complete disappearance of the paper in the air is quite startling.

**Pharaoh's Serpents.** This old chemical curiosity is put up in various forms, one of which is a cardboard or silver-paper cone. All you have to do is to place the cone on a tray and apply a lighted match to the top of the cone. A black snake-like growth emerges from the cone and twists itself over the tray to a length of two or three feet. This is another case where it is difficult to believe that so much can come from so little.

The chemical on which this trick is based is mercuric thiocyanate. As the fumes given off while the 'snake' is emerging are somewhat poisonous, it is wise to open the door for a minute or two at the conclusion of the trick to let a good draught of air into the room.

**A Chemical Snowstorm.** The material for this again takes

<sup>1</sup> An address from which chemical specialities can be bought is 'The Wizard's Den,' Moorfields, Liverpool, 2.



various forms. The chemical is sometimes sold as small pellets which have to be touched with a lighted cigarette; sometimes it is packed in a small cone which has to be ignited. In either case heating causes a cloud of white wispy flakes to be given off. These float about in the air and then settle down slowly, presenting the illusion of falling snowflakes.

The chemical usually employed for making chemical snowstorms is called metdehyde. It is sold cheaply in tablet form by gardeners' supply shops for killing slugs. If you place one of the tablets on a tin-lid and touch it with the blade of an old knife which has been strongly heated you will get clouds of chemical 'snow' given off into the air.

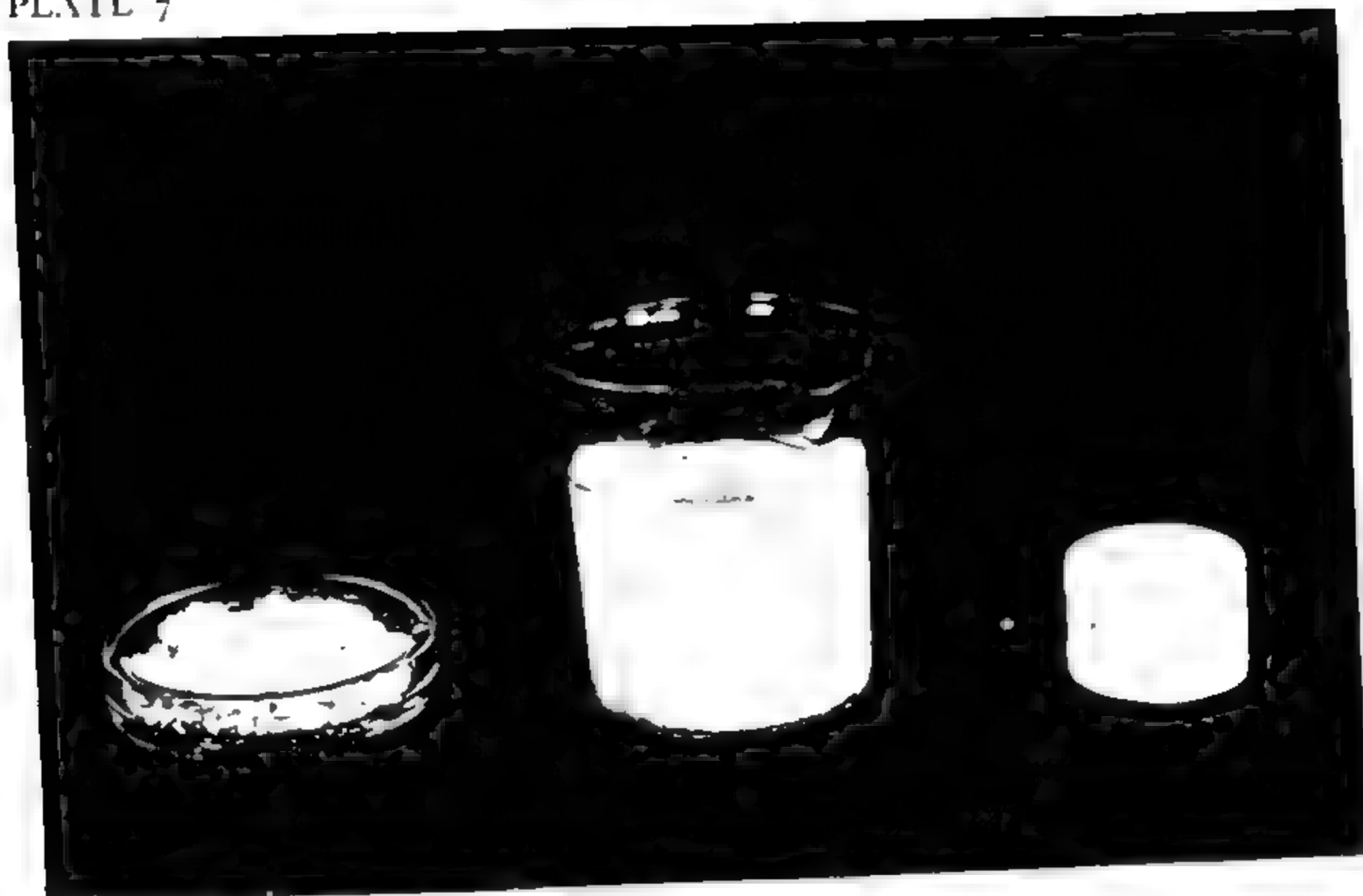
### *An Exhibition of Crystals*

If you have grown some good specimens of crystals as described in Chapter VII considerable interest will be created if you display them. The following hints will help you to show off your specimens to the best advantage.

Glass always enhances the beauty of crystals. Therefore if you can procure some sheets of glass or some small glass plates, set out your crystals on them after polishing the glass. Alternatively, rest the crystals on the rims of glass egg-cups or small drinking-glasses.

Arrange crystals at different levels. This can be done by setting some out on a small table and some on a box on the table. Cover the table and box with black, or at least dark, cloth. A dark background shows up the lustre of the crystals better than a light one.

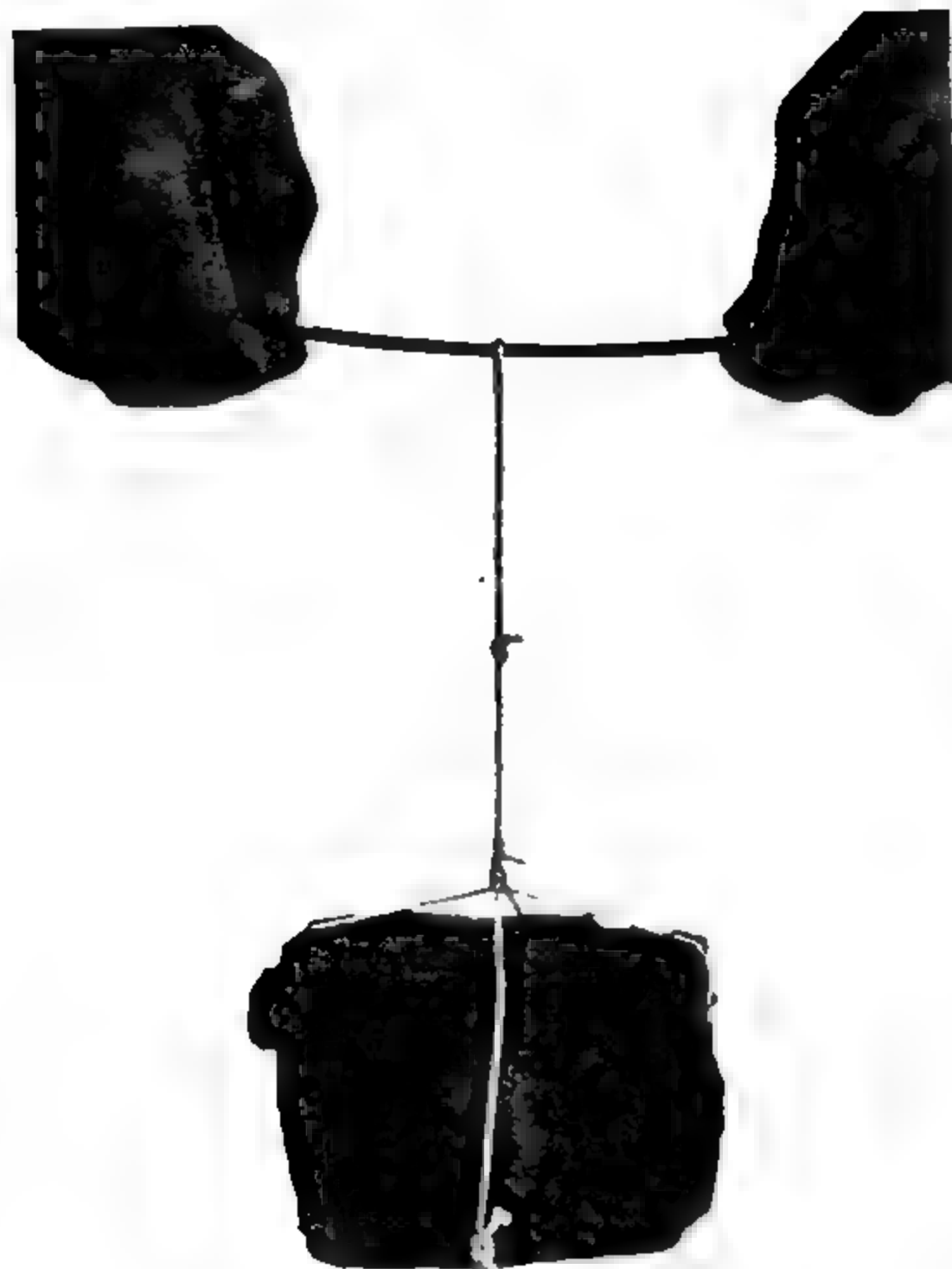
Print prominently on separate cards the names of the chemicals of which the crystals are composed and place the cards in front of the appropriate crystals. Finally print also on a card the request "Please do not handle" and put this where it can be seen. If you allow people to handle your exhibits, the moisture from their hands will quickly spoil the appearance of the crystals.



STAGES IN MAKING A TABLE-NAPKIN RING FROM CASEIN  
The raw casein, the formaldehyde treatment, and the finished article  
(See p. 210)



STAGES IN MAKING AN EGG-CUP FROM UREA-FORMALDEHYDE PLASTIC  
The resin, the egg-cup and mould opened out, and the finished article  
(See p. 210)



HALF A BRICK SUPPORTED  
BY SIX STRIPS OF BLOTTING-  
PAPER IMPREGNATED WITH  
UREA-FORMALDEHYDE  
PLASTIC  
[See p. 215]



HOME-MADE ARTICLES IN PLASTIC  
The two ash-trays and match-holder from urea-formaldehyde, the rest from plain  
or coloured Perspex.

## CHAPTER X

### *Electricity and Chemistry*

Most schoolboys know that electricity is a form of energy and that one kind of energy can be changed into another kind. Chemicals possess energy which is called chemical energy, and the burning of coal or wood is an illustration of the changing of chemical energy into heat energy and light energy.

A common transformation is that of chemical energy into electricity. Indeed, the electricity used in everyday life comes from chemical energy in the first place. At power-stations coal is burned to make the steam which drives the dynamos in which electricity is generated.

On a smaller scale, electricity can be obtained from accumulators and cells only because in these certain chemical actions occur giving the energy which appears as electricity. It is quite easy to make electric cells at home by putting together the proper chemicals in the right way.

#### *Making Electric Cells*

The ordinary simple cell consists of a zinc plate and a copper plate dipping into dilute sulphuric acid. Fig. 59 shows how you can fit up this simple cell.

A zinc strip can be cut from the metal containers inside an old flashlight battery (see p. 196). In place of a copper strip a copper coin can be used. Before using them rub the surfaces of the metals with sandpaper to clean them. Tie the strips of copper and zinc with cotton to opposite sides of a somewhat larger strip of cardboard.

You will require two lengths, each about a foot long, of insulated copper wire. Rub the bare ends of the wires with sandpaper to make sure that your connexions will be good. Attach the end of one wire to the top of the zinc and that of the other to the copper. Binding-screws for this purpose can be bought cheaply at an electrician's, but you can make quite good connexions by means of wire paper-clips, as shown in Fig. 59(a).

Use a flashlight bulb (2.5 volts) to test for the current. A loose socket into which the bulb can be screwed can be obtained for a few coppers at Woolworth's. Connect the other two ends of the wires to the socket. If no socket is available you can still test for the current by holding the end of one wire against the bottom of the bulb and the end of the other wire against the casing.

A small glass jar serves as a cell. Fill the jar about three-quarters full with dilute sulphuric acid. When you have made the connexions, as shown in Fig. 59 (b), dip the metals into the acid, but do not immerse the paper-clips. The combination of zinc and copper only gives about 1.1 volts, but this is sufficient to light up a 2.5 volt flashlight bulb. The direction of the current is from copper to zinc.<sup>1</sup>

Keep the metals in the acid for a few minutes. You will notice bubbles of gas coming from both metal surfaces. The gas is hydrogen.

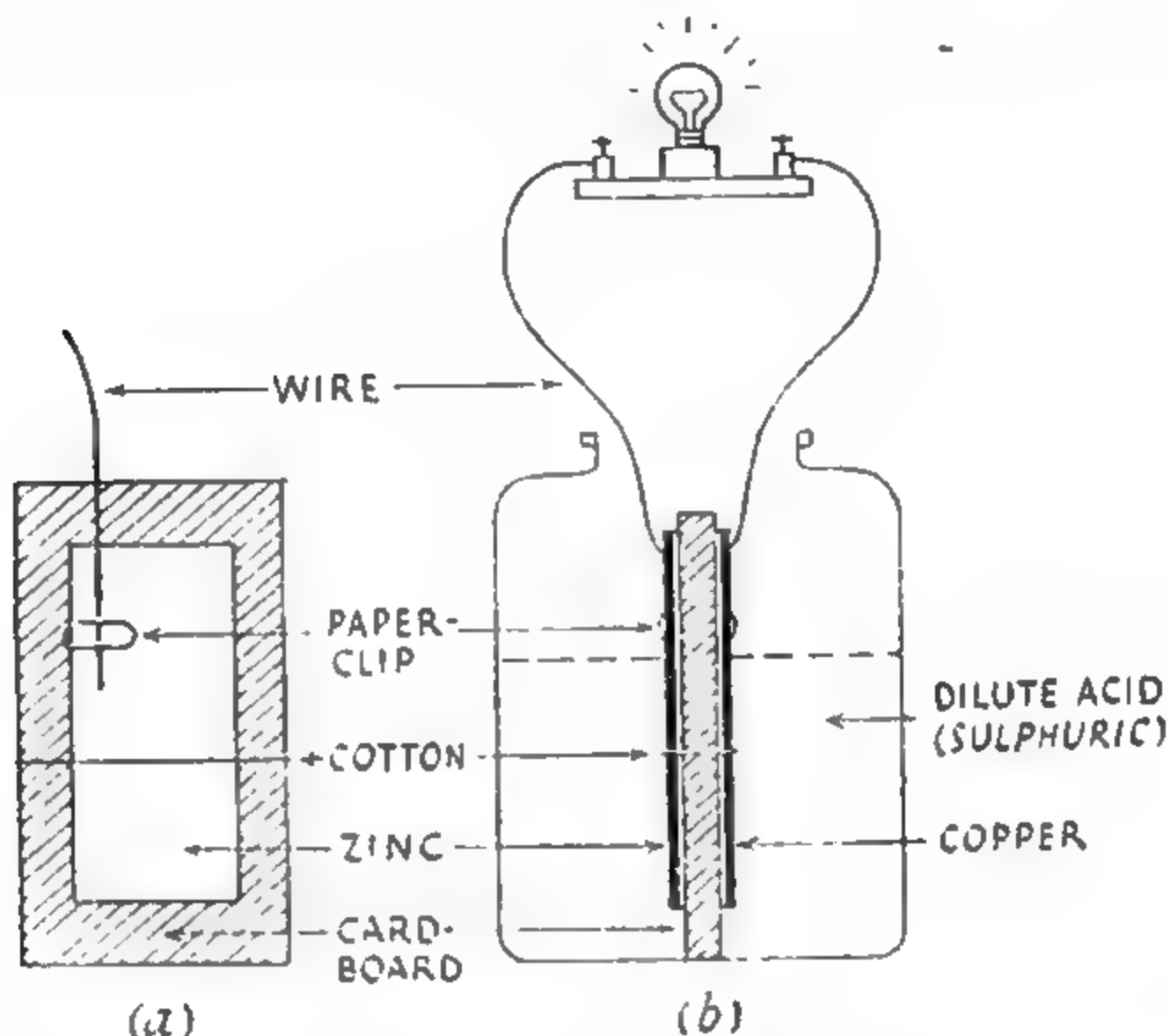


FIG. 59. METHOD OF FITTING UP A SIMPLE CELL

With the above arrangement the current decreases quickly in strength, and becomes so weak in a few minutes that the bulb will not light. This effect is caused by the hydrogen collecting on the copper strip. The hydrogen not only covers up some of the copper but also tends to send a current round in the opposite direction. The effect, which is called 'polarization,' can largely be prevented by adding to the acid a few drops of strong hydrogen peroxide, potassium chromate, or similar oxidizing agent. This removes the hydrogen by oxidizing it to water.

Simple cells can be made from other materials besides zinc, copper, and dilute sulphuric acid. The zinc can be replaced by iron and the copper by lead, silver, or carbon. Instead of dilute sulphuric acid a strong solution of ammonium chloride (sal-ammoniac) can

<sup>1</sup> This can be easily remembered as follows: *o* in copper for 'out,' *in* in zinc for 'in.'

be used. You might try these substances in different combinations. For iron use an old safety-razor blade or a nail. A strip of lead can be cut from an old tooth-paste tube. A silver coin provides the silver, and a carbon rod can be obtained from an old flashlight battery. Set up the cells as described previously, but remember to clean the surfaces of the metals before using them.

Although all the combinations mentioned produce a current, this in some cases is too weak to light up a flashlight bulb. A more sensitive current-detector, however, can easily be made as described in the next section.

This will reveal the current with almost all the different combinations.

**A Sensitive Current-detector.** You will need a magnet and a needle. A small horseshoe magnet of the kind commonly sold as a toy is quite satisfactory. Lay the needle on a sheet of paper and stroke one pole of the magnet along the needle from one end to the other about a dozen times, always stroking in the same direction. This will magnetize the needle with a north pole at one end and a south pole at the other. Tie a length of mending-silk round the middle of the needle and suspend the needle from a knitting-needle (not a steel one) wedged between the top of a jar and a book (Fig. 60). The needle should come to rest with one end pointing towards the north, providing you have removed all objects made of iron from the vicinity.

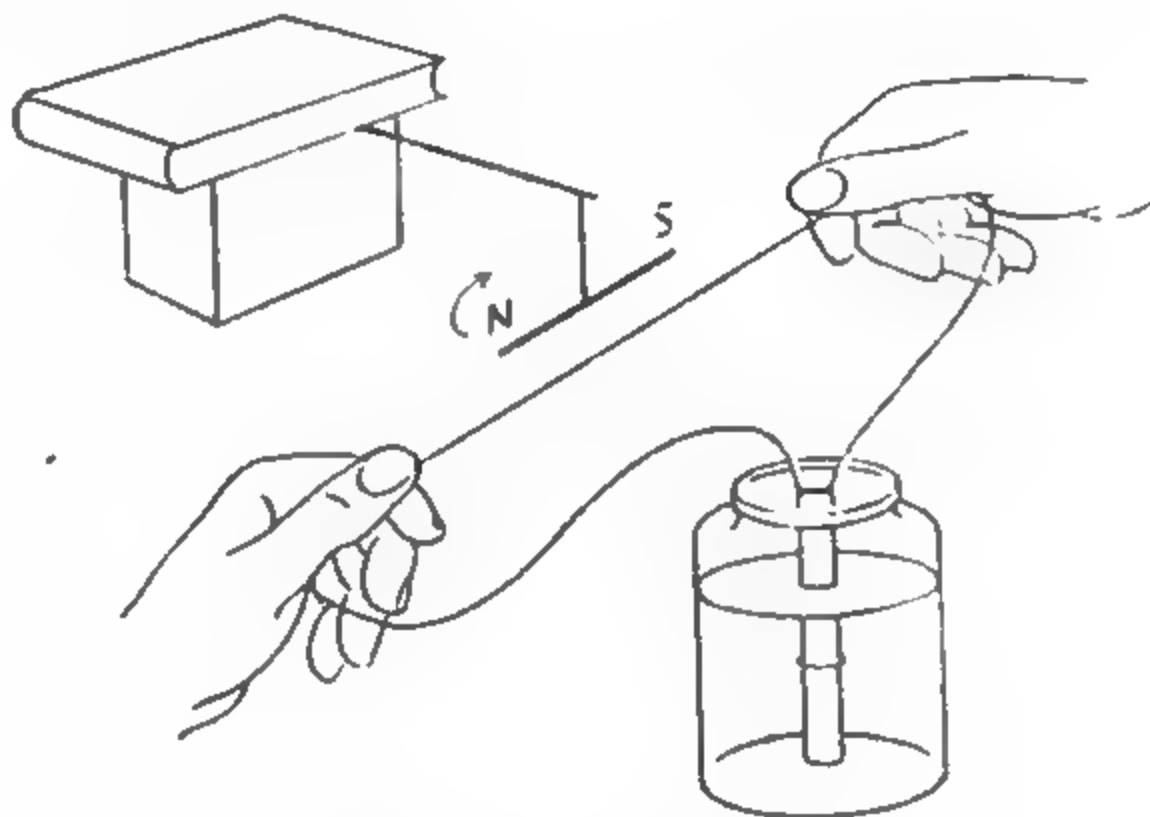


FIG. 60. METHOD OF DETECTING A WEAK CURRENT

The current is detected by holding the wire from the cell parallel to the magnetized needle and just below it. With even quite small currents the needle will swing round so that it tends to lie across the wire. There is a well-known law of electricity, called Ampère's Rule, which you can test by means of the simple apparatus described. Ampère's Rule states: Imagine a man to be swimming in the wire in the same direction as the current and with his face towards the needle, then the north pole of the needle will swing towards his left hand. In our case, of course, where the wire is held below the needle, the man would be swimming on his back.

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**The Parts of a Dry-cell.** If you have performed the experiments already described you will be able to understand the construction of the kind of dry-cell which is used in a flashlight battery. It is a simple matter to remove the paper wrapping and take a cell to pieces. The layer of pitch by which the cell is sealed is best removed by softening it by heat, after which it can be scraped away with a penknife.

The construction of a dry-cell is shown in Fig. 61. It will be seen that this kind of cell is only a modification of one of the simple cells previously mentioned. The essential parts are the zinc case, the

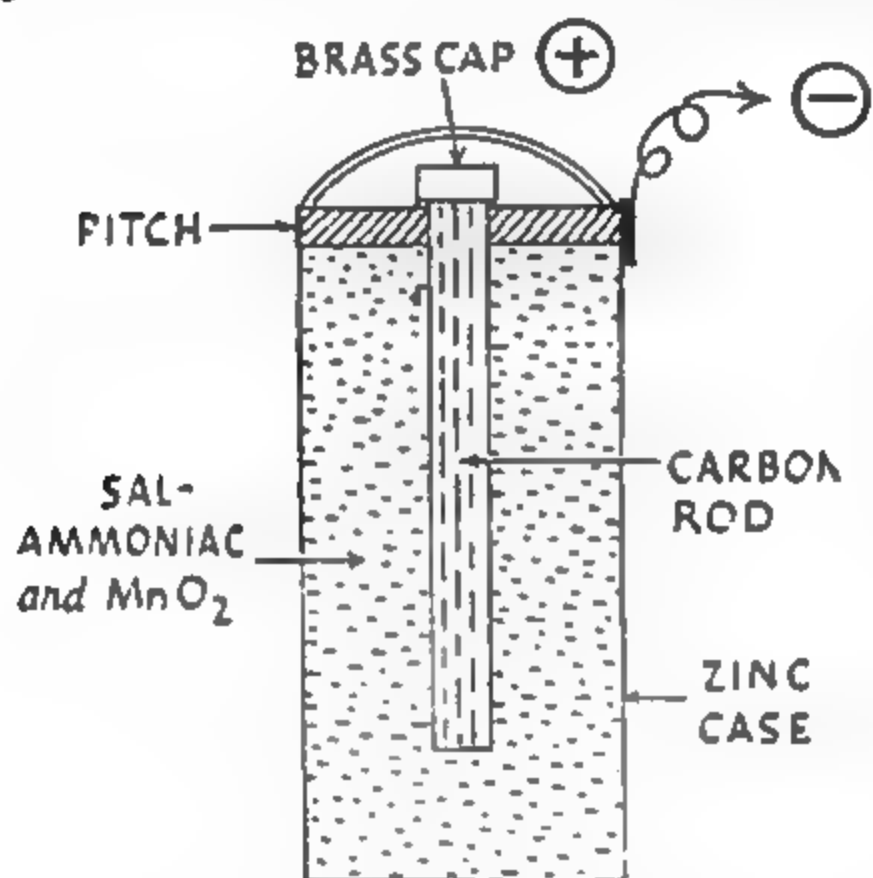


FIG. 61. THE INTERIOR OF A DRY-CELL

carbon rod, and the sal-ammoniac (ammonium chloride).

Mixed with the sal-ammoniac, however is a black powder, manganese dioxide. The purpose of the latter is to oxidize to water the hydrogen which is formed at the carbon rod when the cell is working. The oxidation of the hydrogen is slow, and if the cell is used for a long period at a stretch the hydrogen accumulates at the carbon rod, and the current falls off. Actually, the cell is not dry. Its successful working

depends on the contents being slightly damp. Some carbon is also added to the black mixture to improve the conductivity.

The flat type of flashlight battery contains three cells, the positive terminal of one cell being connected to the negative terminal of the next one. This is called connecting in series. It produces three times the voltage given by a single cell, which is about 1.45 volts.

Old flashlight batteries can provide the amateur chemist with some useful materials for his experiments. From them can be obtained zinc, carbon rods, sal-ammoniac, and manganese dioxide. The method of separating the last two substances from the mixture is described at p. 59.

### *Experiments on Electrolysis*

'Electrolysis' is the name given to the decomposing of substances (usually in solution) by an electric current. Only certain kinds of substances—acids, alkalis, and salts—can be decomposed in this way, because these are the only classes of chemicals which will conduct electricity when dissolved in water. Such substances are called

'electrolytes.' Substances, like sugar, which do not conduct a current in solution and are not decomposed are called 'non-electrolytes.'

You can do experiments on electrolysis with an ordinary flashlight battery, but owing to the low voltage of the latter, the actions are rather slow. If funds permit, it is worth buying a low-tension grid-bias battery, for about one and sixpence, from a wireless shop. From this battery you can tap off various voltages up to 9 volts as you wish. You can then carry out the electrolysis of water and solutions of common salt, copper sulphate, and ferrous sulphate as well as several other interesting experiments. You should buy at the same time two 'wander plugs' for plugging into the battery.

*Experiments on electrolysis using mains current are extremely dangerous and should not be attempted at home. In any case, the domestic supply is usually alternating current, which cannot be used for these experiments.*

### Testing for Electrolytes and Non-electrolytes.

Set up the apparatus shown in Fig. 62. You can do this experiment with a flashlight battery. With a grid-bias battery 3 volts is a sufficient voltage to use. Put some water (rain-water or distilled water is best) into the egg-cup and dip into it the bare ends of the wires from the battery and the bulb. Hold the ends of the wires about half an inch apart in the water. The bulb will not light up, showing that pure water does not conduct electricity.

Remove the wires from the water, add a pinch of sugar to the egg-cup, and stir until it has dissolved. Then introduce the wires again. Still no light will appear. Sugar solution does not conduct a current.

Again remove the wires, and dissolve a pinch of salt in the water. When you test again the bulb will light up immediately, showing that salt solution is an excellent conductor of electricity.

Other chemicals which you can test in the same way to discover whether they are electrolytes or non-electrolytes are washing-soda, sulphuric acid, glucose, vinegar, alum, and glycerine.

**An Apparatus for Electrolysis.** To investigate the products formed by decomposing substances with an electric current you will

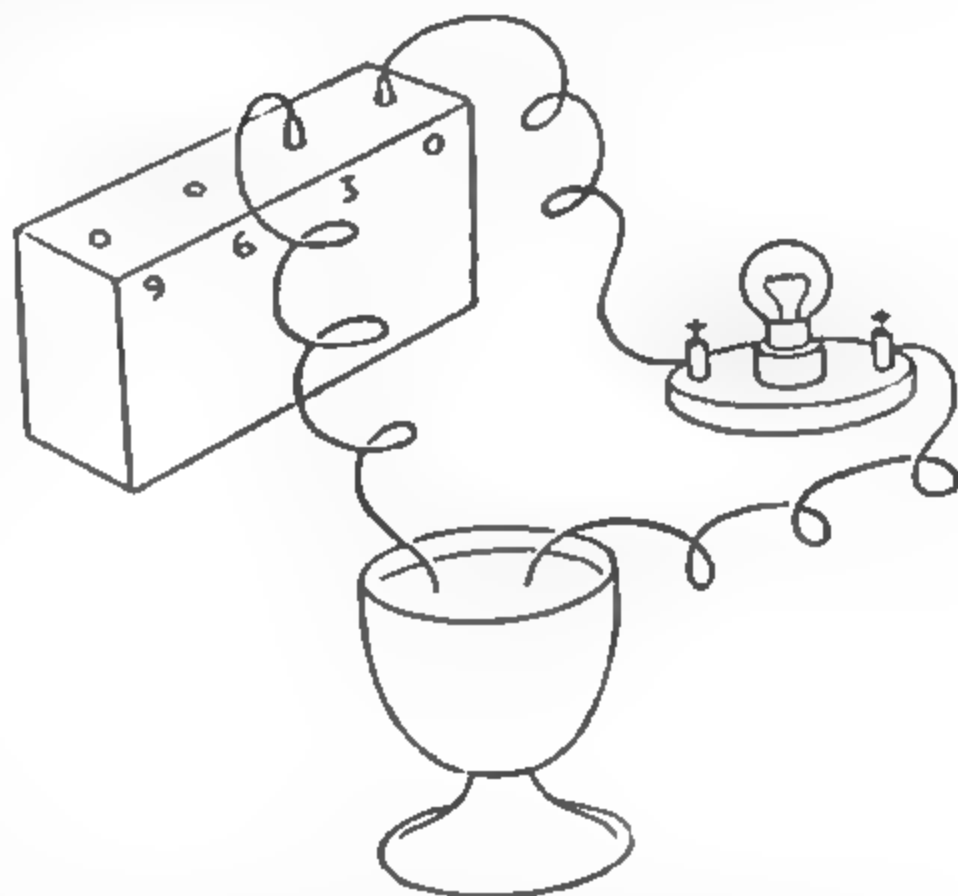


FIG. 62. APPARATUS USED FOR TESTING FOR ELECTROLYTES

need an electrolysis vessel, so that any gases which are given off can be collected. The most convenient vessel to use for the purpose is a cardboard ice-cream carton or drinking-cup about three inches high and two and a half inches across the top. The complete apparatus is illustrated in Fig. 63.

Two carbon rods are needed to act as electrodes. These can be obtained from flashlight batteries. In the flat type of battery there are two brass strips, a longer one and a shorter one, used for making connexions. The shorter strip is soldered on to the cap covering a

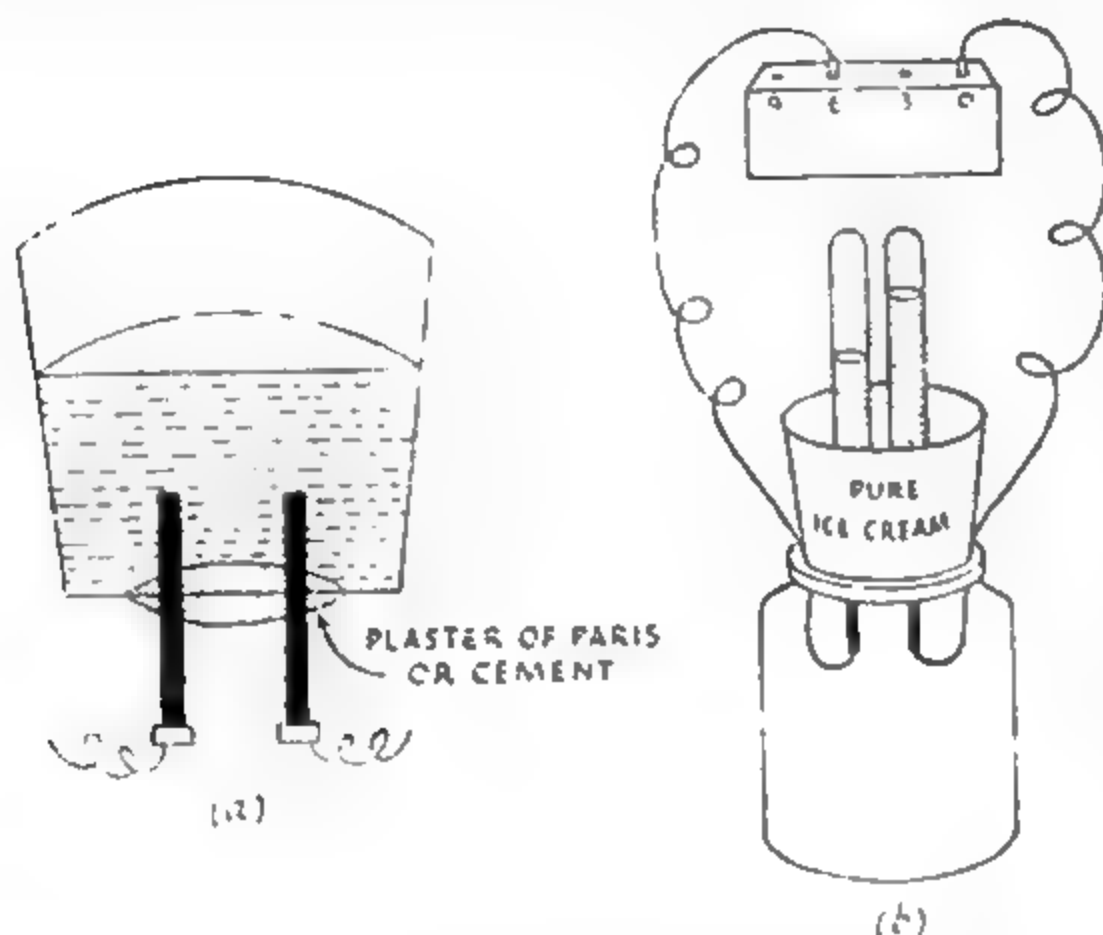


FIG. 63. METHOD OF USING AN ICE-CREAM CARTON TO CARRY OUT ELECTROLYSIS

carbon rod. If you obtain two of these carbon rods from two old batteries you will have ready-made connexions. Otherwise you will either have to buy two small 'Bulldog' clips or make connexions by wrapping bare wire tightly round the rods.

Push the carbon rods through holes in the bottom of the cardboard carton so that the rods are about half an inch apart. About

an inch of each rod should project into the carton. Seal the rods in place by means of plaster of Paris or cement (Fig. 63 (a)). If you use plaster of Paris mix it with cold tea to delay the time of setting; with cement use water. Press a little of the stiff paste around the carbon rods on both sides of the carton and leave it for twenty-four hours to set. The vessel will then be quite watertight.

Rub the brass strips connected to the carbon rods with sandpaper, and attach wires to them with wire paper-clips or binding-screws. Rest the carton in the top of a jam-jar, as shown in Fig. 63 (b). Connect the other ends of the wires to the grid-bias battery. A voltage of 6 or 7.5 volts is usually sufficient. Collect the gases given off at the carbon rods by filling two test-tubes with whatever liquid is being electrolyzed (see next section), inverting the tubes, and placing them over the carbon rods.

An alternative vessel for electrolysis can be made by moulding modelling-clay to the required shape, taking care to make the walls thick enough to avoid the danger of their collapsing and spilling the

liquid. It is more difficult in this case, however, to render the apparatus watertight.

**Obtaining Hydrogen and Oxygen from Water by Electrolysis.** This experiment is carried out in the electrolysis vessel described in the previous section.

Water ( $H_2O$ ) contains twice as much hydrogen as oxygen by volume, and when it is electrolyzed under the right conditions the two gases are given off in these proportions.

Pure water is almost a non-conductor of electricity. Therefore it is necessary to add to the water some chemical which will give a conducting solution but which is not decomposed itself by the electric current. Dilute sulphuric acid is generally used for this purpose, but is not recommended here because it is essential to employ platinum electrodes with the acid to obtain two volumes of hydrogen to one volume of oxygen. With carbon electrodes in dilute sulphuric acid hydrogen is readily evolved but little oxygen is obtained.

The best solution to use with carbon electrodes is one of washing-soda or sodium carbonate. Make the solution fairly strong by dissolving four or five teaspoonfuls of the chemical in a beakerful of water. Connect to the grid-bias battery so as to use 7.5 volts. Collect the gases given off from the electrodes in inverted test-tubes filled with the same washing-soda solution. Wash your hands immediately after placing the tubes in the liquid, as the latter is a fairly strong alkali and may damage your skin if it is not removed.

Oxygen is given off at the positive carbon rod (the anode) and hydrogen at the negative carbon rod (the cathode). The proportions of the gases will be nearly in the ratio 1:2. You should collect a test-tubeful of hydrogen in about fifteen minutes. After stopping the current, remove the test-tubes in turn and test for hydrogen and oxygen in the usual way. Wash your hands again when the tests are completed.

**Making Bleaching Fluid (Sodium Hypochlorite) by Electrolysis.** The industrial process for making bleaching fluid is quite easy to imitate at home. It consists of electrolyzing a solution of common salt.

First make a strong solution of salt by dissolving as much as possible in half a beakerful of water. While it is dissolving cut out a piece of cardboard or several folds of paper in the form of a wedge to fit into the middle of your electrolysis vessel between the carbon rods (Fig. 64). In this way the vessel will be divided into two compartments.

Fill the vessel (which should be washed out well if it has been used before) about two-thirds full with the salt solution and put a piece

of red litmus paper in each compartment. Make the electrical connexions to the grid-bias battery so as to use 7.5 volts.

Bubbles of gas will be given off immediately from one carbon rod (the cathode). This gas is hydrogen. For a time no gas will be set free at the other carbon rod. This is because the gas liberated at the anode—chlorine—is somewhat soluble in the solution, and no chlorine bubbles will appear until the liquid around the anode

has become saturated with the gas. This stage takes about twenty minutes to reach.

After a time you will notice that the litmus paper in the anode (+ve) compartment is being bleached, while that in the cathode (—ve) compartment is turning blue. The bleaching of the litmus paper is brought about by the chlorine and the turning blue of the other piece by the alkali sodium hydroxide which is formed at the cathode.

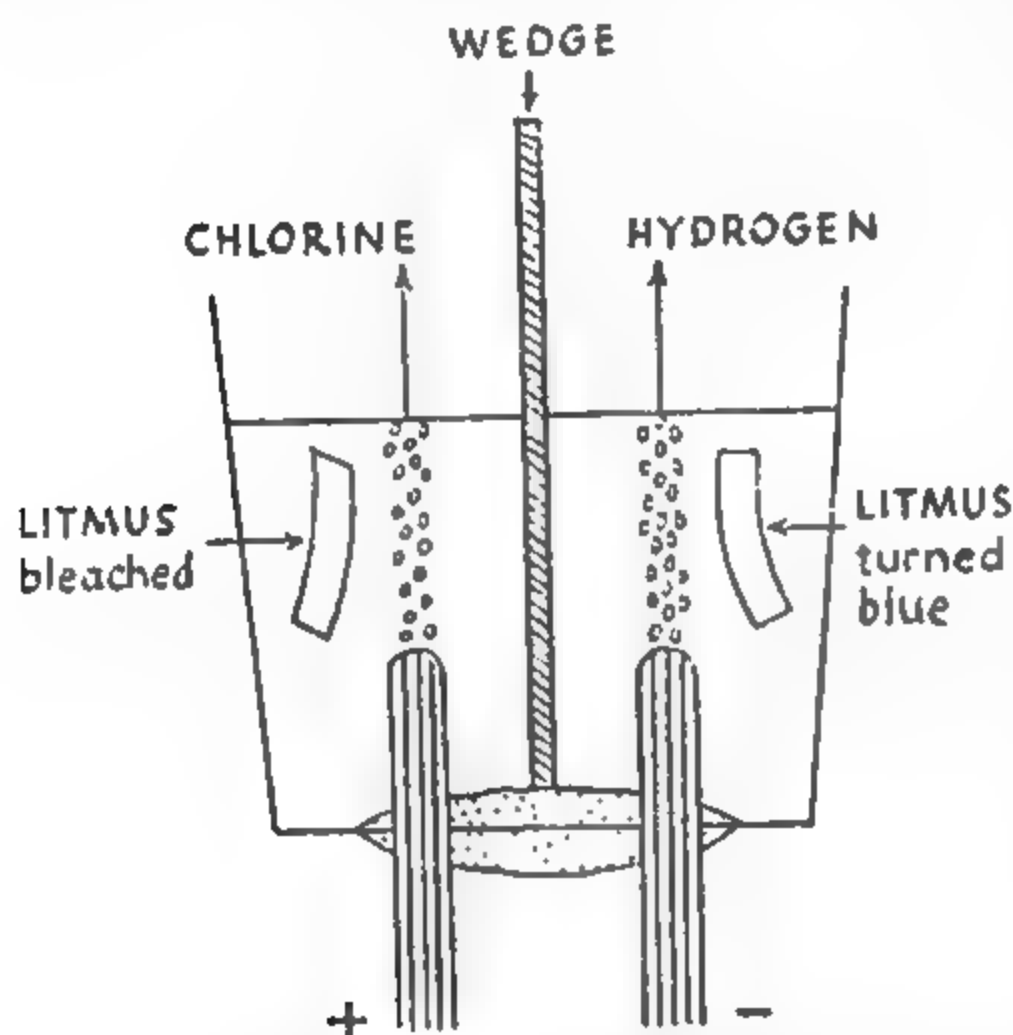


FIG. 64. ELECTROLYSIS OF SALT SOLUTION

When the experiment has proceeded long enough for chlorine bubbles to appear stop the current. Remove the paper wedge and stir the liquid in the vessel to mix it. This causes the chlorine solution in one compartment to act with the sodium hydroxide solution in the other and form sodium hypochlorite. This is the chemical compound which is contained in bleaching fluids. You can test it by adding a drop of ink to some water in a test-tube and then pouring in a little of the solution. The ink will be bleached. Another method of testing the solution is by putting a few drops into a test-tube, acidifying it with any dilute acid, and noticing the appearance and smell of green chlorine gas.

**Electric Writing.** This is a simple but interesting application of electrolysis. When the bare ends of two wires which are connected to a battery are brought close together, but not touching, on a wet strip of red litmus paper a blue mark is formed round the end of the wire connected to the *negative* terminal. This can be done with an ordinary flashlight battery, but the result is obtained more readily if the full 9 volts from a grid-bias battery are used. By moving the



ends of the wires you can trace out your initials in blue on the red litmus paper.

The reason for the blue mark is that the litmus dye used for colouring the paper is usually a sodium compound of litmus and this compound is electrolyzed by the current. A small amount of the alkali sodium hydroxide is formed round the end of the negative wire as in the electrolysis of salt solution. Indeed, the experiment works better if the litmus paper is soaked in salt solution, which is then electrolyzed with the production of sodium hydroxide at the cathode.

Another kind of paper which can be used for this experiment is made by soaking a piece of filter-paper or white blotting-paper first in salt or sodium sulphate solution and then in phenolphthalein solution. In this case the writing will be red (phenolphthalein turns red with alkalis<sup>1</sup>).

The experiment is sometimes used in electricity to discover which are the positive and negative terminals of a battery or other source of current. Either kind of paper can be used, and the marking of the paper shows which wire is connected to the negative terminal, or 'pole.' The papers used in this way are called 'pole-finding papers.'

### *Electroplating*

'Electroplating' is the covering of the surface of a metal with a layer of another metal by means of electrolysis. The chief reasons for electroplating are to improve the appearance of an article, as in silver-plating or gold-plating, or to increase the resistance to corrosion, as in the chromium-plating of letter-boxes or the nickel-plating of bicycle parts. Electroplating with metals like silver and chromium is too difficult to attempt at home, but copper-plating and iron-plating are easy to do.

**How to Copper-plate Lead.** Obtain a strip of lead from an old tooth-paste tube and a strip of copper. If no copper strip is available a copper coin can be used instead. It is advisable to remove grease from the surfaces of the metals by boiling them for a few minutes in washing-soda solution. Afterwards rub the surfaces with sandpaper until they are bright.

Attach the two metals to a strip of cardboard by means of cotton (see Fig. 59, p. 194). Connect wires to the metal strips by binding-screws or wire paper-clips and connect the other ends of the wires to the grid-bias battery, using 7.5 volts. Make the copper the anode

<sup>1</sup> To avoid holding the two wires close together, the positive wire can be attached to a sheet of metal (e.g., a tin-lid) and the soaked paper laid on the sheet. The writing can then be done easily with the negative wire. The tin-lid must be cleaned with sandpaper so that the bare metal is exposed.



(+ve) and the lead the cathode (—ve). It is a rule of electrolysis that metals (and hydrogen) are set free at the cathode, non-metals (except hydrogen) at the anode. In our case we want copper to be deposited on the lead, and therefore the lead must be made the cathode (Fig. 65).

Put the cardboard and metal strips into a small glass pot and fill this about two-thirds full with copper sulphate solution. A suitable strength for the latter is three teaspoonfuls of powdered copper

sulphate dissolved in half a beakerful of water. In about ten minutes a good layer of copper will be deposited on the lead.

**Iron-plating Copper.** You will remember that it is a simple matter to copper-plate iron merely by dipping the iron into copper sulphate solution. The reverse operation, iron-plating copper, has to be done by electrolysis.

Use the same general arrangement as described in the previous section, but employ an iron anode (an old razor-blade or a nail) and a strip of copper or a copper coin as the cathode. Remember to clean the surfaces. A solution of ferrous sulphate of similar strength to the copper sulphate is used for

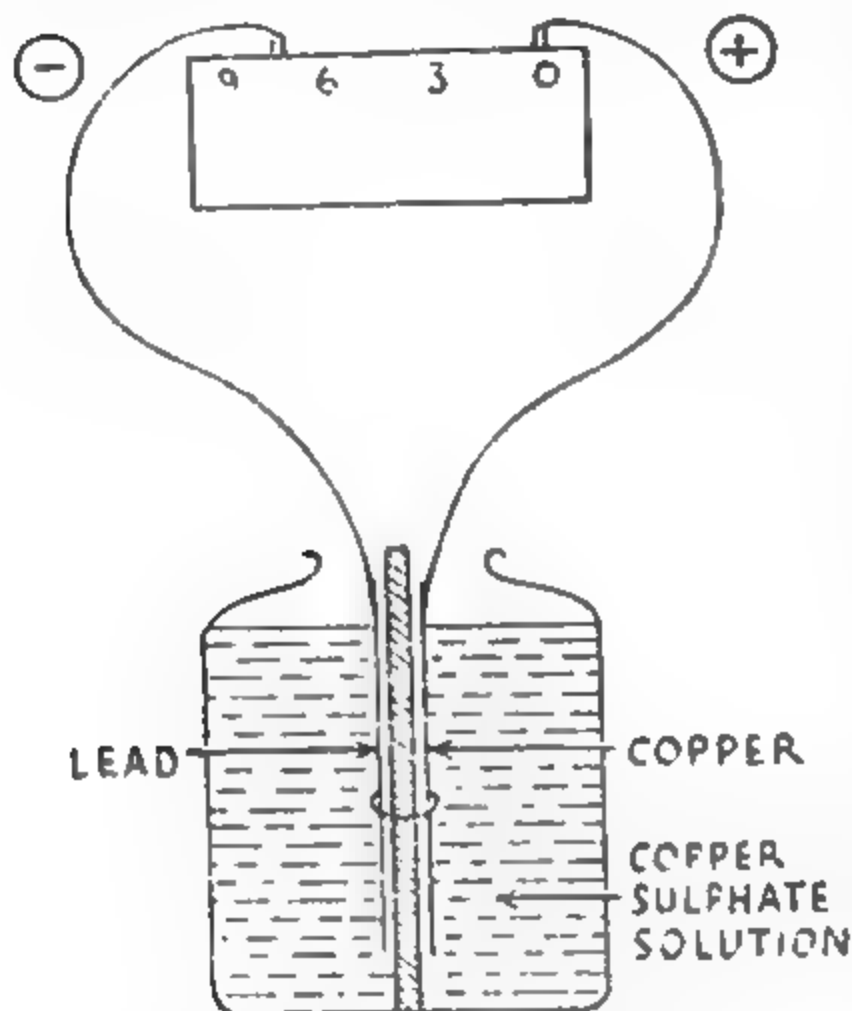


FIG. 65. APPARATUS USED TO COPPER-PLATE LEAD

the electrolysis, although a solution of iron alum will do equally well. Again make the voltage 7.5 volts and pass the current for ten minutes.

The iron which is deposited on the copper is not shiny like ordinary iron but black and spongy. You can prove that it is iron, however, as follows. When the electrolysis is finished cut off a small piece of the copper strip with the black layer and test it with a magnet. It will be attracted by the magnet, owing to the layer of iron. Another test is to drop the coated copper into dilute sulphuric acid and note the appearance of bubbles of hydrogen. Iron, but not copper, gives hydrogen with dilute sulphuric acid.

**Making a Simple Accumulator.** The cells in a flashlight battery or grid-bias battery turn chemical energy into electrical energy. They are 'one-way' cells. When the chemicals are exhausted the battery has to be thrown away. This is not so with an accumulator. The latter also turns chemical energy into electricity,

but when it begins to run down it is not thrown away. Instead it is charged up again by passing a current through it. In this operation the chemicals are re-formed and the electrical energy of the current is stored in the chemicals as chemical energy. Thus an accumulator is a 'two-way' cell, or, as it is called in Science, a 'reversible' cell.

If you examine an accumulator you will notice that it contains two alternate sets of plates, one grey and the other brown, immersed in a liquid. The grey plates are made of lead mesh and are coated with spongy lead. The brown plates are also made of lead mesh but are coated with brown lead dioxide ( $\text{PbO}_2$ ). The liquid is dilute sulphuric acid (somewhat stronger than ordinary dilute sulphuric acid).

You can easily make a simple accumulator with a small glass pot, a couple of strips of lead from a tooth-paste tube, and some dilute sulphuric acid. As in previous experiments, tie the two strips of lead, after cleaning them thoroughly, to a strip of cardboard with cotton. Connect them to the grid-bias battery, using 6 volts. Fill the glass pot two-thirds full with dilute sulphuric acid. Put the lead strips into the acid and keep the current going for half an hour.

At the end of this time remove the plugs from the battery and connect them at once to a flashlight bulb. The bulb will light up for a short time.

Take the lead strips from the glass pot and examine them. You will find that one has not changed in appearance, but the other one will now have a brown covering of lead dioxide. When you are taking current from your home-made accumulator the lead dioxide is the positive strip and the lead the negative. An accumulator is always charged in the opposite direction to the one in which it gives current—that is, the current is passed *in* at the lead dioxide plate and *out* at the lead plate.

## CHAPTER XI

### *Experiments on Plastics*

(A CHAPTER FOR OLDER BOYS AND GIRLS)

#### *What Plastics are*

NOWADAYS many of the articles which we use in everyday life are being made from plastics. Tooth-brushes, ash-trays, cigarette-cases, combs, buttons, toys, spectacle-frames, fountain-pens, and electric-light switches are a few illustrations of the uses to which these materials can be put. Names of particular plastics like Bakelite, Perspex, and Beetle are becoming familiar to most people, although not so many are aware that there are dozens of different plastics in use at the present time and that new ones are still being discovered.

What is a plastic? Briefly, it is a substance which is soft enough at some stage of its manufacture to be moulded into any desired shape and which can then be hardened so that it keeps that shape. Strictly speaking, clay is a plastic, but the term is usually applied to materials made by chemical processes or which have to undergo chemical treatment before they become useful.

There are two chief classes of plastics, described as 'thermoplastic' and 'thermosetting' respectively. Thermoplastic materials are those which can be softened by heating and hardened again by cooling, and this can be repeated over and over again. You may have noticed on your tooth-brush the instruction, "Do not put into hot water." This instruction is given because the tooth-brush is made of a thermoplastic material (probably cellulose nitrate), and hot water causes it to soften and lose its shape. A thermosetting plastic like Bakelite, however, cannot be made soft by heating it when it has once been hardened.

All modern plastics have one feature in common—they come from very long molecules. If you have studied Organic Chemistry you will be familiar with the chain-like structure of molecules, like that of octane,  $\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_3$ . We have not yet discovered the exact length of the chain-like molecules which make up plastics, but investigation by X-rays has shown that they are some hundreds of times longer than a molecule of octane, although they are still too small to be seen even with a powerful microscope.

Now, millions of years before chemists had begun to think about long molecules Nature herself had made some. Cellulose, the chief

chemical in cotton and wood, is one example of Nature's efforts in this direction. It is not surprising therefore that the first plastics evolved by man were based on naturally occurring substances consisting of long molecules. The story of modern plastics really begins with the discovery by Alexander Parkes of Birmingham, in 1855, that the plastic celluloid could be made from cellulose.

Bakelite, Beetle, and most other modern plastics are derived from man-made long molecules. In some cases these substances were first produced accidentally, but it was not long before chemists noticed the kinds of chemicals which act together to form the long molecules necessary for plastics. The next step was the deliberate creation, starting with likely chemicals, of new substances with long molecules. Out of the researches which followed have come the recent additions, like Perspex, to the plastics list. Closely related to plastics are textile fibres like cotton and wool. These also consist of long molecules, so that we can readily understand why fresh discoveries in the plastics field have been matched by the discovery of new kinds of fibres, such as Nylon and Terylene.

### *Celluloid*

Tooth-brushes, table-tennis balls, white and transparent cycle mudguards, and transparent drawing-instruments are made of celluloid. The starting-point for making celluloid is cotton, which, as stated previously, consists largely of cellulose. The latter chemical is given the formula  $(C_6H_{10}O_5)_n$ , where  $n$  is at present an unknown number (possibly between 100 and 200). The most important feature about the molecule of cellulose after its long chain-like structure is that it contains hydroxyl (OH) groups, which can be exchanged for certain acid groups like the nitrate ( $NO_3$ ) group. This exchange is brought about by treating cotton with a mixture of nitric acid and sulphuric acid, and the ester cellulose nitrate results.

Celluloid is made by dissolving cellulose nitrate in alcohol and mixing the solution with camphor. No chemical action takes place with the camphor. The latter is called a 'plasticizing agent.' It merely acts as an internal lubricant and enables the long molecules of cellulose nitrate to slide easily over each other. The pasty mass is warmed, put into a mould, and squeezed to the shape of the mould in a press. When the celluloid is cooled it hardens and keeps its shape. Alternatively, the celluloid may be rolled out into sheets between heavy rollers. In this way sheets for making photographic film and drawing-instruments are obtained.

**Testing the Properties of Celluloid.** Celluloid is thermo-plastic. If an old transparent tooth-brush is left in a saucepan of boiling water for a few minutes and then removed with a spoon it

can be easily bent. When the tooth-brush has cooled it will retain its new shape. A table-tennis ball which has been accidentally dented can be restored to its original shape by dipping the dented portion into hot water. The celluloid is thereby softened, and the expansion of air inside the ball forces the softened surface into a spherical form again.

The chief drawback in the use of celluloid is its high inflammability. This sometimes leads to fatalities when children's celluloid toys are accidentally set on fire. You can test its inflammability by burning in the fire an old tooth-brush or a strip cut from a transparent protractor. The celluloid will burn quickly and fiercely. On no account should you burn old photographic film while holding it in your hand. The film will flare up and will probably burn your hand. For many purposes (*e.g.*, home-cinema film) ordinary celluloid has been replaced by the safer 'non-flam' celluloid. The latter consists of cellulose acetate, and is described at p. 228.

**Home-made Nail-varnish.** Cellulose nitrate is insoluble in water but it dissolves in amyl acetate or acetone. Amyl acetate is a colourless oily liquid with a strong smell of 'pear-drops' or bananas. It is sometimes called banana-oil. If your mother or sister uses nail-varnish the smell of amyl acetate will be familiar to you, for nail-varnish is a coloured solution of cellulose nitrate in amyl acetate, although to make the solution evaporate more rapidly a volatile liquid like acetone is often included. After the evaporation a shiny film of cellulose nitrate is left on the nails. Acetone is the principal constituent of nail-varnish remover.

Nail-varnish can be made at home from old photographic film, an old tooth-brush, or a transparent protractor or set-square. Small quantities of amyl acetate and acetone are also required. These can be obtained cheaply from a chemist's shop if you take your own bottles. Acetone is a highly inflammable liquid and should never be used with a naked light in the same room. Amyl acetate is not as inflammable as acetone, but it should be kept away from a flame or it may set on fire.

If you are using photographic film, first remove the black layer on it by rubbing with sandpaper. Cut about two square inches of the film into small pieces. If your material is an old tooth-brush, use one of the transparent type. It is scarcely necessary to point out that the colour of the tooth-brush will determine the colour of the nail-varnish which results. Put the tooth-brush in a test-tube and half fill the latter with amyl acetate. Leave the brush standing in the liquid for ten minutes and then remove it and allow it to dry. This will soften the material so that shavings can easily be cut from it with a knife.

Put the pieces of cellulose nitrate into a small bottle and fill the bottle with a mixture of two parts of amyl acetate and one part of acetone. Cork the bottle with a tightly fitting cork. The dissolving of a plastic in a solvent is a much slower process than the dissolving of salt or sugar in water and it will take at least twenty-four hours, with occasional shaking, for the cellulose nitrate to dissolve. Test the solution formed by smearing a little on a finger-nail and allowing it to evaporate.

If the nail-varnish which you have made is colourless it can be coloured by incorporating a small amount of dye. Thus the lead from a red pencil can be crushed and used to impart a light red colour. Congo red will give a dark red shade. A solution of colouring matter like red ink cannot be used because water will not mix with the varnish. The colouring matter should be rubbed thoroughly into a little of the varnish with the back of a spoon in an egg-cup. The coloured liquid is then returned to the bottle, which is well shaken.

### *Artificial Silk*

The most common form of artificial silk is viscose, which consists of practically pure cellulose. When it is in the form of a fibre it is usually called rayon and is used for making stockings, blouses, etc.; in sheet form it is used as wrapping material under the name of Cellophane.

Viscose is not regarded as a true plastic, since it does not go through a moulding process, but it is closely related to the plastics. It is manufactured by dissolving the cellulose from wood pulp in caustic soda and carbon disulphide. The solution is a syrupy, or viscous, liquid which has given rise to the name viscose. The solution is then forced through fine holes into a bath of sulphuric acid, which precipitates the cellulose in the form of fine filaments. These are gathered up and spun into thread. Alternatively, to produce Cellophane, the viscose solution is squeezed through a long, narrow slit in the sulphuric acid bath, and the cellulose is obtained as a thin transparent sheet.

**Making Artificial Silk.** The industrial method of making artificial silk is not a suitable one to imitate under home conditions. The method now described, however, is easy to carry out and was formerly used commercially to make 'cuprammonium silk.' It consists of dissolving cellulose in the form of filter-paper in the deep blue liquid formed when excess of ammonia is added to copper hydroxide. The deep blue solution contains the compound cuprammonium hydroxide.

Put an egg-cupful of strong copper sulphate solution into a beaker.



Add dilute sodium hydroxide solution until no more precipitate of blue copper hydroxide forms. Now add strong ammonia solution to the beaker, drop by drop, and stir at the same time until the copper hydroxide has dissolved, forming a clear deep blue solution. Tear a filter-paper into small pieces and stir these into the liquid. The paper will dissolve and produce a thick viscous solution.

If you can procure a small syringe introduce some of the filter-paper solution into it. To do this you will have to remove the plunger of the syringe. Half fill a beaker with an acid solution

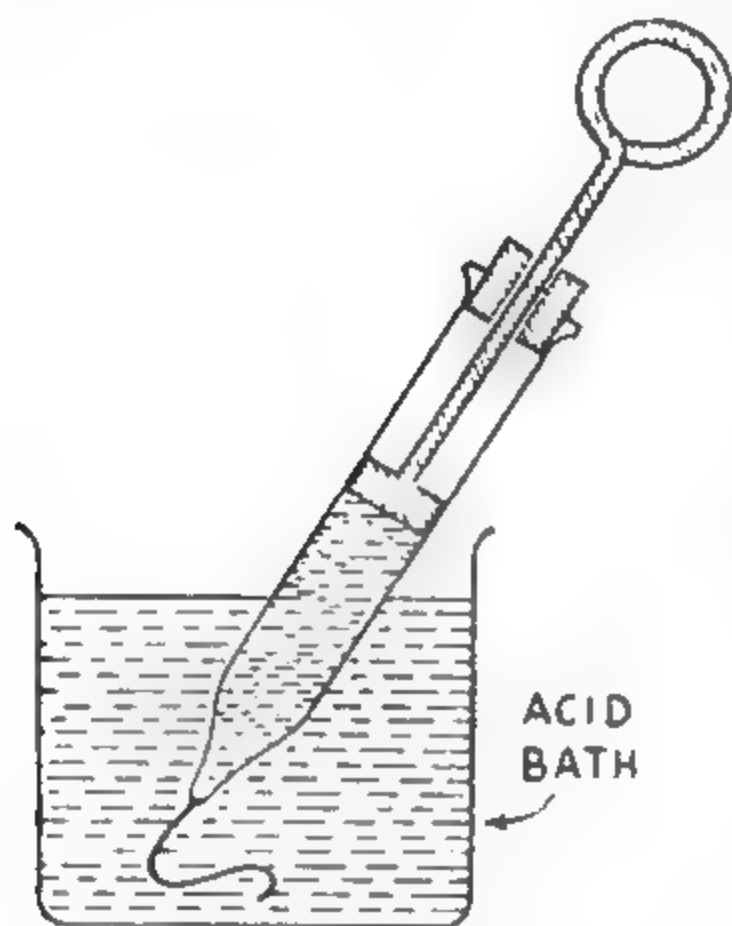


FIG. 66. METHOD OF PRECIPITATING ARTIFICIAL SILK

(dilute sulphuric acid, citric acid, or sodium bisulphate solution). Place the nozzle of the syringe below the acid. Squeeze out the blue solution steadily into the acid, at the same time moving the nozzle about in the liquid. A long blue filament will be formed as the solution comes into contact with the acid (Fig. 66). The filament consists of cellulose, or artificial silk. Leave it in the acid for a while, when it will gradually turn white. Remove it with a spill from the liquid, wash it gently under the tap, and allow it to dry.

If a syringe is not available, a fountain-pen filler with a rubber bulb or even a length of glass tubing can be used instead. Pour the filter-paper solution into a test-tube and partly fill the glass tube by lowering it into the solution.

### *Casein Plastic*

Milk is the basis of one important branch of the plastics industry. 87 lb. of every 100 lb. of milk consists of water. The remainder is made up chiefly of fat, milk-sugar, or lactose, and casein. Casein is a complex chemical of unknown formula, but it is known to contain carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. There is about half an ounce of casein (in the form of a colloidal suspension) in one pint of milk.

Casein can be precipitated from milk by means of acids, as described at p. 106. In industry the precipitation is carried out with rennet, an extract from the stomach of the calf (rennet is used at home for making junket). After the cream has been separated the skimmed milk is warmed and treated with rennet. The precipitated casein is mixed with hot water and made into a dough,

which is then pressed into sheets or forced through holes to form rods.

Before it can be used to make articles the casein has to undergo a chemical treatment. This consists of soaking the sheets or rods in a solution of formaldehyde, which hardens them. The hardening process is slow, and some months are required for this stage to be completed. Eventually, however, a hard, strong product results. This is made into buttons, buckles, combs, dominoes, knitting-needles, and many other articles in everyday use.

Casein plastic differs from most other plastics in that objects are not made from it by being pressed into shape in a mould. Instead the sheets and rods, after the formaldehyde treatment, are shaped and cut by tools like saws and drills. Casein plastic is thermosetting, but objects made from it are softened by immersion in boiling water owing to the water being absorbed.

**Making Articles with Casein Plastic.** The making of casein plastic and its conversion into useful articles like table-napkin rings, ash-trays, match-holders, etc., are well within the compass of the amateur chemist. Ordinary milk, sour milk, or dried milk can be used. Ordinary milk should be allowed to stand for a time and the top layer of cream skimmed off. Dried milk should first be reconstituted by mixing it with warm water in accordance with the instructions given on the tin (except that more casein can be obtained by making a strong solution).

Formaldehyde solution will also be required. Formaldehyde is a gas, but a strong (40 per cent.) solution is sold by chemists under the name of formalin for disinfecting purposes. This solution costs about twopence an ounce, and four ounces will provide sufficient of the chemical not only for the experiments on casein plastic but also for those on urea plastic which are described later. The solution is poisonous and should be kept in a safe place.

The first step is to obtain casein from milk. Put about a quart of the skimmed or reconstituted milk into a saucepan and warm it. Have ready half a cupful of vinegar, very dilute sulphuric acid, or citric acid solution containing two teaspoonfuls of the crystals. When you can just bear your finger in the hot milk pour the acid solution gradually into the saucepan, stirring as you pour. The milk will curdle rapidly, and a white cheese-like mass of casein will be precipitated. Strain off the liquid through a sheet of muslin or an old handkerchief. Gather the cloth with the casein into a ball and dip it a few times into a basin of water to wash out the acid from the casein. Then squeeze out as much moisture as you can. Open out the cloth on a folded newspaper and leave it for half an hour for the paper to absorb most of the remaining moisture.

The next stage, if you desire a coloured product, is the addition of colouring matter. Transfer the casein to a small basin with a spoon and add two or three drops of coloured ink or water-paint. Red ink is quite satisfactory, but do not use blue-black ink, as the colour does not last. You will be surprised by the ease with which the casein takes up the colouring-matter and the resulting vividness of the dyed casein. Mix the dye in well with a spoon until an even shade is obtained.

To make, say, a table-napkin ring you will require a mould of suitable size and shape. You should bear in mind that considerable shrinkage will occur during the hardening treatment and the finished object will be only one-half to two-thirds the size of the same object in the mould. A beaker or mug with straight sides serves admirably as a mould.

Transfer to the beaker or mug a few spoonfuls of the casein and shape it with the back of a spoon to form a ring around the sides at the bottom of the vessel (see Plate 7). A suitable size to aim at is a ring about three inches wide, two inches high, and a quarter of an inch thick. When making the ring press the pasty mass against the sides of the container to squeeze out bubbles trapped in the casein (with a glass beaker you can see when this has been accomplished). Finally smooth the inside of the ring so that the sides are straight.

The next stage is the formaldehyde treatment, but before starting this it is as well to leave the beaker or mug standing for an hour or two in a warm place, such as the bottom of the airing-cupboard. This will partially dry the ring, so that it will not fall to pieces in the formaldehyde solution. Meanwhile prepare the latter. In industry a 5 per cent. concentration of formaldehyde is employed, but it is advisable for you to use a slightly stronger solution. Dilute some of the 40 per cent. formalin to about five times its volume with water, remembering that only a beakerful or mugful of the diluted solution is needed. Pour the diluted solution into the beaker or mug until the ring is covered, and leave it on a saucer on a shelf.

The soaking in formaldehyde should last for about two days. At the end of this time simply pour away the solution, and replace the vessel on the shelf without touching the ring. Wait for another three or four days, when it will be found that the ring has shrunk away from the sides of the container. Remove the ring carefully, place it on the saucer, and leave it now for two or three weeks without interfering with it. Although not finally hardened, the ring will now be strong enough for you to handle gently. Shape the top and bottom of the ring with an old razor-blade, and smooth away any unevenness on the sides by rubbing them with fine sandpaper. Only gentle pressure should be applied, and it is best to hold the

ring in one hand while you use the sandpaper with the other. When the smoothing is completed to your satisfaction again leave the ring for the hardening to continue.

The hardening process lasts for two or three months, but at the end of five or six weeks the ring will be quite hard and strong, and you can apply the final treatment. Another rubbing with fine sandpaper will probably be required to produce a smooth finish. To make the surface shiny, polish it well with a good brand of metal polish, or paint it with a quick-drying lacquer. You will now have a table-napkin ring similar to the one shown in Plate 7.

Other objects can be made with casein plastic by the same method. The same beaker or mug will also serve as a mould for a match-holder. In this case the bottom as well as the sides of the vessel should be covered with a layer of casein. To make an ash-tray, use an ash-tray or saucer as the mould, and stand this in a soup plate for the formaldehyde treatment. If modelling-clay is available you can fashion moulds of various shapes and make a wide variety of articles.

Casein plastic can be bought in sheet form and used in constructing useful objects. The handling of this material is described at p. 229.

**Repairing a Cracked Beaker with Casein Glue.** Plastics are used for other purposes besides making articles. One use is as adhesives or glues to make things stick together. Casein is sometimes used in this way, although not as frequently as urea plastic, which is described later. A good glue can be made by dissolving casein in a strong solution of borax. The glue can be used for repairing a cracked beaker and thus prolonging its usefulness. The glue can also be used to seal a cracked jug or vase.

To make the glue, put a teaspoonful of casein into a cup or beaker and add a strong solution of borax, a little at a time, stirring until the casein has dissolved. A creamy liquid will be obtained. Take a strip of rubber and rub one side of it with sandpaper to clean and roughen the surface. Apply the casein solution to the cleaned surface and press the rubber over the crack in the beaker. Leave the beaker undisturbed for a couple of days, when the rubber will have become firmly cemented to the beaker. Although the beaker cannot be heated, it will now be quite watertight.

### *Bakelite*

A great advance in plastics was made when chemists found out how to make substances consisting of long molecules from substances consisting of short molecules. The first synthetic plastic resulting from this discovery was Bakelite, which was discovered by an American chemist, Dr L. H. Baekeland, in 1909.

Bakelite is made from phenol, or carbolic acid, and formaldehyde.

When these substances are heated together with a catalyst they undergo a condensation process whereby water is eliminated and some hundreds of the phenol molecules become joined together in long chains by means of the formaldehyde molecules. Representing the phenol molecules by large circles and the formaldehyde molecules by small circles and omitting the water which is formed, we can indicate the change simply as shown in Fig. 67.

Readers who have a knowledge of the chemical formulæ of

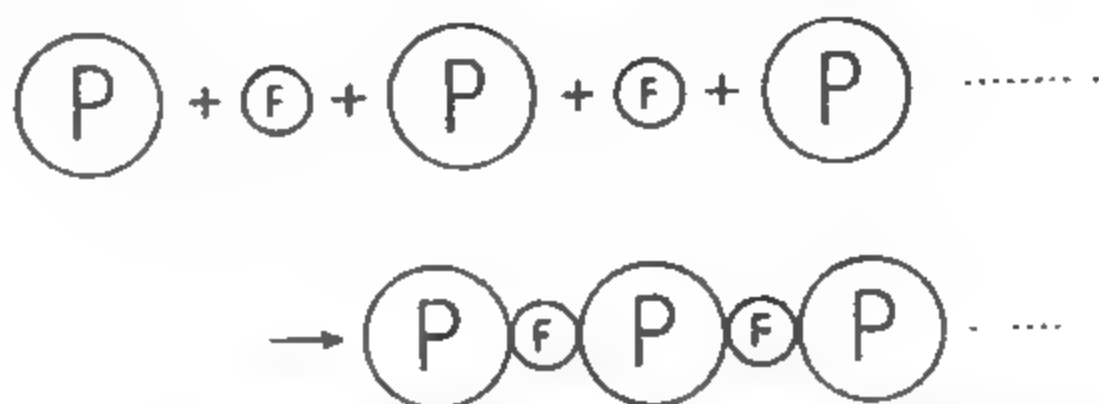
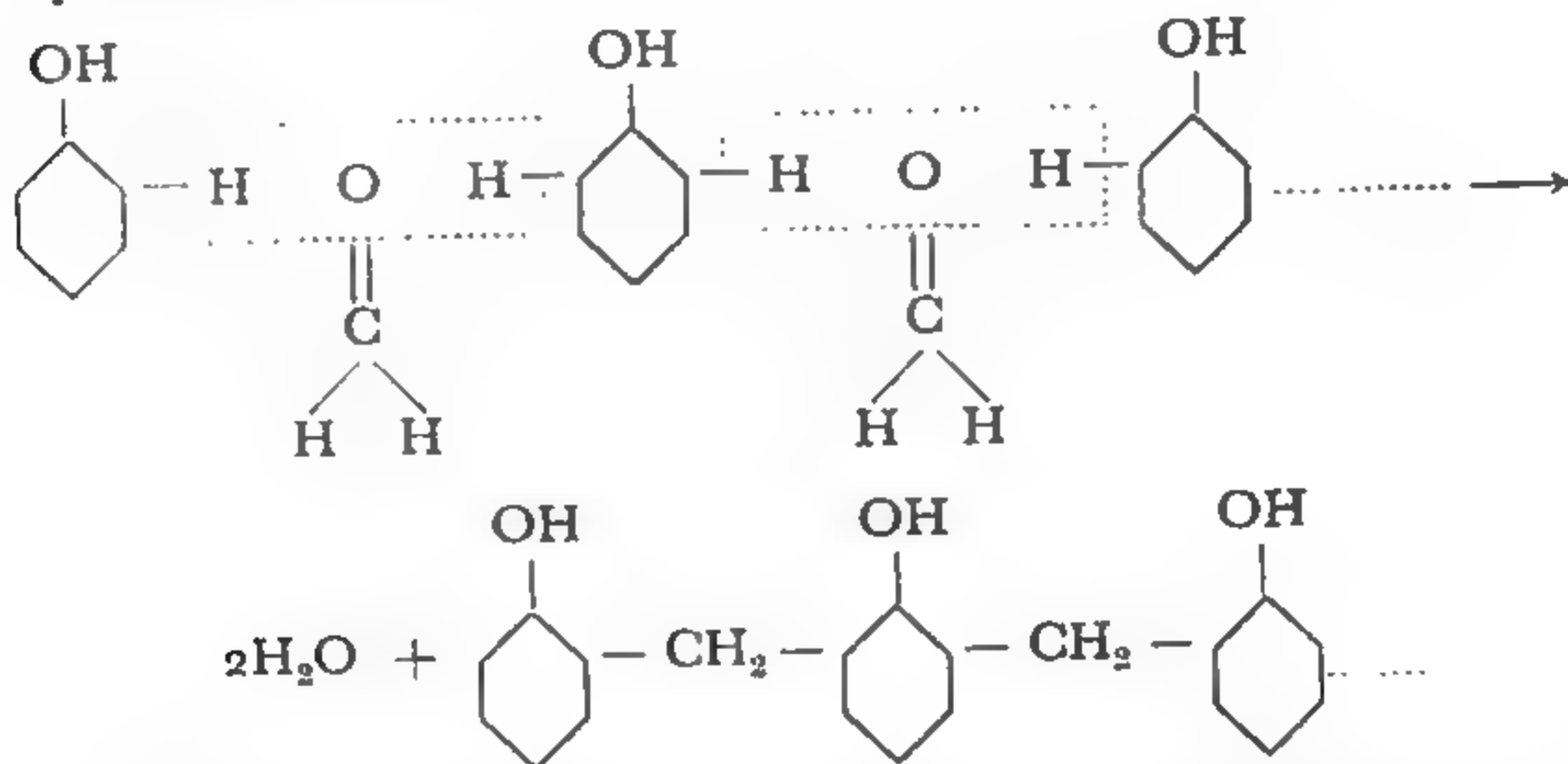


FIG. 67. THE JOINING TOGETHER OF PHENOL MOLECULES BY FORMALDEHYDE MOLECULES

organic substances may be interested to see the proper chemical equation which is:



The product is a resinous substance (most plastics have a resin-like form in the early stage of their manufacture). The resin is dried, ground to a powder, and mixed with a 'filler' to give it body. The usual filler is 'wood flour,' which consists of finely ground wood. The mixture is fed into a heated steel mould shaped like an ash-tray, a tumbler, etc. A hydraulic press is then closed, and in a few seconds the mixture is pressed to the shape of the mould and at the same time hardened.

Bakelite is thermosetting. The reason for this lies in the change which occurs in the press. Under the influence of heat and pressure



the long molecules of the resin are made to join sideways by the formaldehyde molecules still present. The result is a closely interconnected network in space which cannot be disintegrated by heat. It is a single 'giant molecule.' The structure thus differs fundamentally from that of a thermoplastic material like cellulose nitrate, which consists of long molecules lying more or less side by side.

Phenol is too dangerous a chemical for anybody but experienced chemists to use and therefore experiments on Bakelite are not given here. A safer material of a similar type to prepare is urea plastic. This can be made at home, as described in the next section.

### *Urea Plastic*

Many of the gaily coloured articles of everyday life, such as egg-cups, spoons, and tumblers, are made from urea plastic, which is called by various trade names, one of the best known being Beetle.

Urea is a white, crystalline, deliquescent substance having the chemical formula  $\text{CO}(\text{NH}_2)_2$ . When urea is heated with formaldehyde solution it undergoes a condensation process similar to the one which occurs with phenol and formaldehyde and a creamy resin is formed. There are two ways of hardening the resin: (i) by heating it, and (ii) by treating it with acids. Both methods result in cross-linking of the long molecules of the resin, so that the final product is thermosetting, like Bakelite.

The manufacture of moulded articles from urea plastic is similar to that used for Bakelite. The resin is dried, ground to a powder, and mixed with a suitable filler (wood flour, shredded paper, asbestos, etc.). The mixture is then moulded in a press while heat is applied.

The resin is also widely used as an adhesive or glue, and for this purpose an acid is often employed as the hardening agent. The time required for hardening depends on the strength of the acid. With a dilute mineral acid like sulphuric acid hardening takes place in a few minutes, but with weak organic acids two or three hours are needed.

Synthetic glues of the Beetle type are replacing animal glue in many directions. They are used to make plywood, which, besides being immune to the action of the weather, is much stronger than ordinary plywood. Sheets of paper, linen, and asbestos are also 'bonded' together by means of urea plastic. These laminated plastics, as they are called, are used for the manufacture of aeroplane fuselages, airscrews, table-tops, gear wheels, control panels, electrical insulating material, and dozens of other purposes.

**Making Urea Plastic.** Urea can usually be bought at the chemist's. It costs fourpence or fivepence an ounce, and two ounces will suffice for the experiments described.



The only other chemical required is about three ounces of the 40 per cent formaldehyde solution, mentioned at p. 209. A certain amount of formaldehyde gas is given off in the preparation of the plastic. This gas is poisonous in large quantities, but you can safely use the solution in the amounts given. Even in small quantities, however, the gas is irritating to the eyes and nose, and to avoid discomfort it is advisable to have doors and windows open so that there is good ventilation. It is as well also to choose a time for your experiments when nobody else is about.

To make the resin, put an egg-cupful of urea crystals and two egg-cupfuls of the 40 per cent. formaldehyde solution into a clean beaker. Without heating, stir the liquid until the crystals have all, or nearly all, dissolved. Then warm the solution over a gauze and tripod while continuing the stirring. When the liquid begins to boil a fairly vigorous action will set in, and in a few seconds the contents of the beaker will turn creamy in colour. At this stage pick up the beaker in a cloth and carry it outside into the open air, holding your breath as you do so. Allow the beaker to cool outside. The thick white resin which remains is used for the experiments now described.

Before using the resin it is a good plan to leave it for twenty-four hours, during which time any excess of formaldehyde will largely disappear. This precaution is not essential if hardening is carried out with acid, but it should certainly be taken if hardening by heat is attempted, otherwise uncomfortable quantities of formaldehyde will be given off. To economize in the use of the resin, decide on which experiments you wish to try, and get all your materials ready beforehand.

**Experiments with Urea Plastic.** First try different fillers with the resin, and use an acid as the hardening agent. Suitable fillers to try are sawdust, cotton-wool, blotting-paper, cardboard, and sand. The best acid to use for hardening is citric acid solution (one small teaspoonful of crystals to half a cupful of water). Vinegar, sulphuric acid, or sodium bisulphate solution can be used, but the last two should be in very weak concentration or hardening will be too rapid. A teaspoonful of dilute sulphuric acid to a beakerful of water is a suitable strength.

Half fill an egg-cup with the resin, add three or four drops of acid of the strength mentioned previously, and mix well. In another egg-cup put a couple of teaspoonfuls of sawdust or sand, and stir into this just sufficient of the acidified resin to make a stiff paste. Transfer the paste to a tin-lid. Similarly soak in the resin a small wad of cotton-wool, a little blotting-paper, and a small piece of cardboard which has been roughened with sandpaper. Place the

treated articles on the lid and leave them for a few hours in a warm place, such as the bottom of the airing-cupboard. You will find that they become quite hard.

**Making Laminated Plastics.** You might try next the making of a laminated plastic with strips of cardboard or blotting-paper, and if an oven is available heat might be used as the method of hardening. This experiment demonstrates very well the strength which is imparted to materials by the plastic.

Cut four strips of cardboard or six strips of blotting-paper, each strip measuring about six inches long and one inch wide. Roughen the surfaces of the cardboard strips by rubbing them with sandpaper. The resin does not require acidifying when hardening is carried out with heat. Paint the resin with a small brush over the surface of the strips. The two strips which are to be on the outside need painting only on one side. Let the resin soak into the cardboard for a few minutes and then apply a second coating. Place the strips on top of each other and press them firmly together.

Leave the strips for half an hour in a slightly warm oven to dry out. Examine the strips to make sure that they appear to be dry and then increase the heat of the oven to medium heat. Leave the strips exposed to this heat for ten minutes. When they are removed from the oven it will be found that they have become firmly cemented to one another. Any gaps between the strips are due to incomplete drying in the first stage in the oven.

The strips of blotting-paper can be bonded in a similar manner. To test the strength of the laminated plastic, tie some string round half a brick and make a loop in the other end of the string. Pass the loop over the compound strip of cardboard or blotting-paper and hold the ends of the strip in your hands. The strip should support the weight of the half-brick (see Plate 8). This test is usually successful if the plastic has been hardened in the oven.

**Safety-glass.** This kind of glass is used for the windscreens of motor-cars, and has done much to reduce the injuries which result from flying glass when an accident occurs. Safety-glass consists of a thin sheet of plastic sandwiched between two sheets of ordinary glass. When broken it does not splinter, because the tiny fragments of glass are held together by the plastic.

Cellulose acetate is the usual plastic employed in making safety-glass, but urea plastic can be used for the same purpose. You can make safety-glass at home by cementing together two pieces of glass with urea resin. Either method of hardening can be used.

**Making an Ash-tray.** If you are interested in plastics you will probably want to attempt the making of some article, such as an ash-tray or an egg-cup. We shall describe first how you can make

an ash-tray, using cotton-wool as the filler for the resin. The most convenient method of hardening is by means of acid.

In the first place, you will require a mould to give the shape. You can either use an ash-tray as a mould, or construct a mould of suitable shape from modelling-clay. From a roll of cotton-wool detach a strip of sufficient size to cover the mould and about quarter of an inch thick. Trim the cotton-wool roughly to shape. Acidify about two egg-cupfuls of the resin as described previously and add a drop or two of coloured ink (not blue-black) or a little water-paint.

Rub some grease or margarine over the top surface of the mould to prevent the cotton-wool from sticking to the surface. Place the mould on a plate and pour about half an egg-cupful of the coloured resin into the mould. Lay the cotton-wool over the surface and press it down with the back of a spoon. The resin will soak into the cotton-wool. Transfer more of the resin to the cotton-wool with the spoon until the whole of the cotton-wool has been impregnated. Press the wet material closely to the surface of the mould with the spoon.

Leave the plate and its contents in a warm place, such as the airing-cupboard, for twenty-four hours. The cotton-wool should then be dry and hard. Loosen it in the mould by running a penknife blade round the edge, after which it should lift out easily. If the bottom of the new ash-tray is not dry and firm, leave it for a further period with the lower side uppermost.

The final shaping of the edge can be carried out by cutting with an old razor-blade and rubbing firstly with a small file and then with fine sandpaper. If you want to make the job still stronger, rub the entire surface with fine sandpaper, apply another coating of the resin, and dry as before. To make the surface of the ash-tray shiny, polish it with a good metal polish, or paint it with a quick-drying lacquer.

Both of the ash-trays shown in Plate 8 have been made with urea plastic. For the larger one cotton-wool was used as the filler, and for the smaller one fine sawdust (see the next section) was employed.

**Making an Egg-cup.** For this experiment the best filler to use is fine sawdust. A near approach to the wood flour used as a filler in industry can be made by rubbing a piece of soft wood across a nutmeg-grater. This produces very fine shreds of wood. Alternatively, you can shake some sawdust in a coffee-sieve and use the fine particles which pass through the sieve. Plate 7 illustrates the stages in making an egg-cup.

Construct a mould by pressing modelling-clay round an egg-cup (the type without a foot should be used). Cut the clay down opposite sides, remove the egg-cup, and re-join the sides of the clay. Mix an egg-cupful of the acidified resin with the finely shredded wood or

sawdust until a stiff paste is obtained. A little colouring matter can also be incorporated at this stage. Grease the sides of the mould and line the bottom and sides with the paste.

In this experiment the process of drying is not as easily accomplished owing to the shape of the mould, but it can be accelerated as follows. After leaving the mould and its contents on a saucer in a warm place for twenty-four hours make cuts down the side of the mould in three or four places. Carefully turn down the strips of clay so that the new egg-cup is exposed. Leave it like this for another twenty-four hours to complete the drying and hardening. Smooth the sides of the egg-cup by rubbing firstly with a file and then with fine sandpaper. Finally polish the sides with metal-polish or apply a coating of lacquer.

## CHAPTER XII

### *Working with Sheet Plastic*

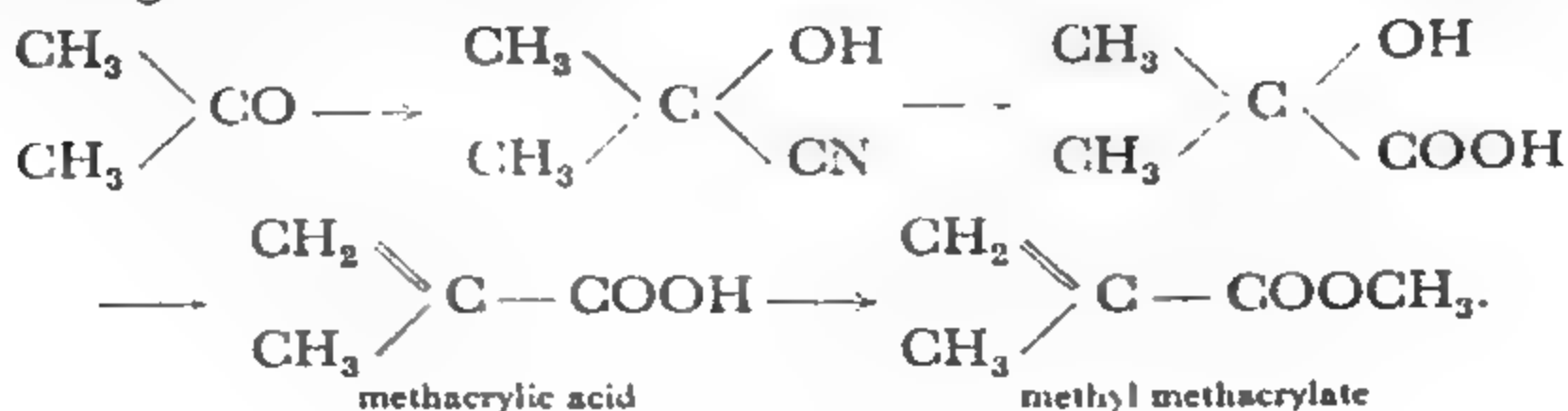
In this chapter we shall describe the handling of some of the modern plastics which can be bought in sheet form. Although the working of sheet plastic belongs more to the field of Handicrafts than of Chemistry, the materials employed are of great interest to chemists. The making of useful or decorative articles from the sheets not only gives an insight into the properties of the plastics but is a fascinating activity in itself.

The following pages deal with Perspex, cellulose acetate, and casein plastic. All three materials can be readily cut with a fine-toothed saw and the first two can be softened by heating or immersion in boiling water, so that with the help of a few simple tools the amateur can make such objects as toys, trays, cigarette-cases, trinket-boxes, toast-racks, etc. Some home-made articles of this kind are illustrated in Plate 8. When the working principles involved in handling the materials have been learned the variety of articles which can be constructed is limited only by the enthusiasm and ingenuity of the worker. Addresses from which plastic materials can be bought are given at the end of the Chapter.

#### *Perspex*

Perspex is the trade-name of a product manufactured by I.C.I. (Plastics) Ltd. In America a similar material is called Lucite. Perspex is sometimes described as an organic glass, because the transparent sheet has the appearance of glass. It is much less brittle than glass, however. Another difference is the remarkable clarity of Perspex which gives articles made from it a truly brilliant and beautiful appearance.

Chemically Perspex consists of polymerized methyl methacrylate, and is manufactured from acetone and hydrogen cyanide. Those readers who are keen on Organic Chemistry will be interested to know the various stages representing the manufacturing process. The stages are as follows:



The change of acetone cyanhydrin to methacrylic acid is effected with sulphuric acid, and the acid is converted into the methyl ester by means of methyl alcohol. Finally the ester is polymerized and a transparent sheet obtained by heating the ester with a catalyst between glass plates.

Polymerized methyl methacrylate is also manufactured as a moulding-powder in the form of small spheres. In this form it is known as Diakon and is used for making dentures.

Perspex is sold in transparent or opaque sheets, and both kinds can be obtained in a variety of colours. The sheets are supplied in standard thicknesses, such as  $\frac{1}{4}$ ,  $\frac{3}{16}$ ,  $\frac{1}{8}$ , and  $\frac{1}{16}$  in. Until the reader acquires experience in handling the plastic he is advised to limit his work to the  $\frac{1}{16}$  in. thickness. The cost of the material is liable to fluctuation, but at the time of publishing is five to seven shillings per square foot for the thinner varieties. Coloured sheets are somewhat dearer. For the beginner an economical method of purchase is to buy 'offcut' sheets. These consist of odd pieces of material of different thicknesses left over from manufacturing operations, and cost about seven shillings per lb.

**Operations involved in handling Perspex.** (i) *Cutting.* The usual tool for cutting Perspex is a fine-toothed saw. Suitable kinds of saw are a hacksaw, a fretsaw, or tenon-saw. For small cuts (up to three inches long) a small hacksaw, costing about a shilling and known to ironmongers as the 'Junior' hacksaw, is very convenient. Perspex sheet is usually supplied with a white paper-covering to protect it from scratches. The line of cutting should be marked out on the paper-covering with a pencil and ruler. If the covering becomes removed, the marking can be done on the material with a sharply-pointed knife or a nail which has been sharpened to a point with a file.

It is necessary to use a lubricant for the saw in cutting Perspex, otherwise the saw will 'bind' very readily and the material will probably snap. The best lubricant is water, with a smear of soap along both sides of the blade. To avoid clogging, the saw should be kept as free as possible from 'swarf' (the dust produced by sawing), and the lubricant should be renewed frequently.

Another method of cutting Perspex is with the heated blade of an old penknife. This will first soften the material and then cut through it. The blade should be thin and not heated to such an extent that it causes the material to blacken. This method of cutting does not leave as clean an edge on the sheet as a saw, but it has the advantage that it can be used to cut curves which otherwise require the use of a fretsaw.

When the sheet is being cut to measurements a margin (say  $\frac{1}{16}$  in.) should always be allowed for finishing off the rough edges.



(ii) *Smoothing Edges.* After the sheet has been cut sharp or rough edges will remain. The roughness should be removed by rubbing with a small triangular file and then with fine sandpaper. Prolonged rubbing with a file will cause it to 'glaze' due to finely powdered material, and the file should be cleaned now and then with a stiff brush under running water.

After the rubbing treatment the edges will have a 'frosted' appearance, which provides a striking contrast to the clarity of the transparent faces. The 'frosted' surface can be made transparent, if desired, by polishing as described later.

(iii) *Bevelling or rounding Edges.* These operations are usually carried out with a file, followed by fine sandpaper, although special engraving tools can be bought for the purpose.

(iv) *Softening.* Before the sheet can be bent or moulded it has to be softened. Perspex is a thermoplastic material. It can be softened to some extent by immersion in boiling water for two or three minutes, but the degree of softening is sufficient for only small jobs. The best temperature to use for softening is about  $130^{\circ}\text{C.}$ , which can be attained in the household gas or electric oven. The latter should be regulated to slightly below medium heat. The material under treatment should be placed on an asbestos mat in the upper part of the oven and left for two or three minutes. The mat and the material are then removed with a cloth, when it should be found that the Perspex is pliable like a sheet of soft rubber. 'Blistering' of the material indicates that too high a temperature has been used. A preliminary trial with a small test-piece of the sheet will guard against this happening.

(v) *Bending.* This is accomplished by wrapping the softened sheet round some object which has the desired shape. Thus if a circular curve is to be produced the sheet is wrapped round a cylindrical tin of suitable diameter. A right-angled bend can be made with the help of a square tin. The object used for shaping the material should be made of metal or wood and not of glass. The latter is liable to crack with the heat.

The length of time for which the heated plastic will remain soft enough for working depends on the thickness of the sheet. Sheets  $\frac{1}{8}$  in. thick will retain their working heat for about 25 seconds, those  $\frac{1}{4}$  in. thick for about 40 seconds.

If your first attempt at bending is unsuccessful, you need not despair. All you need to do is to return the material to the oven. It will soften and straighten itself into sheet once more, and another attempt can then be made. This can be repeated over and over again if necessary.

(vi) *Moulding.* Moulding differs from bending in that the softened

sheet is pressed into a given shape. The production of complicated shapes by moulding is too difficult for the amateur to attempt, but simple mouldings can easily be carried out. A cavity mould can be cut out of wood with the help of a fretsaw or can be made in a container with plaster of Paris as described later. In either case a 'plunger' which has the same shape as the mould is required for pressing the sheet into the mould.

The excess of material (called the 'flash') which remains attached to the moulding is removed with a fretsaw or by means of a heated penknife blade. When the flash is being removed a margin must be allowed for the subsequent filing and finishing off of the edges.

(vii) *Cementing Pieces together.* To join separate pieces of Perspex, a special cement called Diakon cement is required. This can be bought from the addresses given at the end of the chapter for 2s. to 2s. 6d. per small bottle. The cement is economical to use, as very little is needed on each occasion.<sup>1</sup>

The cement contains a solvent which evaporates quickly, so that the liquid hardens rapidly after it has been applied. It should not be applied with a brush or the latter will be rendered unfit for further use by the coating of hardened cement which is left on it. The best way of applying the cement is by means of a twisted paper spill, which can be thrown away afterwards. The cement should be used sparingly, so that no liquid is squeezed out when the pieces are pressed together.

Slight pressure is desirable in joining the pieces. A vice can sometimes be used if it is available. Otherwise the pieces should be pressed together by hand for two or three minutes. When the pieces have been joined they should be left undisturbed for an hour or two.

(viii) *Polishing.* One of the chief faults of Perspex is that it scratches rather easily. Providing the scratches are not too deep, they can be removed by rubbing the surface well first with a good brand of metal polish, and then with Silvo silver polish. Separate cloths should be used with each polish. Frosted surfaces can be made transparent again in the same way.

Another method of treatment is to use two special polishes which can be bought. These are known as Perspex polish No. 1 and Perspex polish No. 2, and each costs about 2s. 6d. per tin. These polishes are applied in turn to the surface of the material.

(ix) *Making Holes.* It is sometimes necessary to make small holes, for riveting two pieces of Perspex together or for making hinges (e.g., for a box-lid). A riveted joint is usually stronger than one

<sup>1</sup> A suitable cement can be made by dissolving small fragments of Perspex (such as 'swarf') in the liquid trichlorethylene.

which is merely cemented. Small rivets and hinges can be cut from a wire paper-clip.

The best way of making the holes is by means of a twist drill of suitable size ( $\frac{1}{16}$  in.). To prevent the drill from slipping and scratching the material, the hole should be started with a gimlet or bradawl which has been sharpened to a point. The rivets are afterwards cemented into the holes with Perspex cement.

A quick way of making holes is to heat a short length of wire held in a pair of pliers and press it into the material. This leaves a raised edge around the hole, which makes the method unsuitable

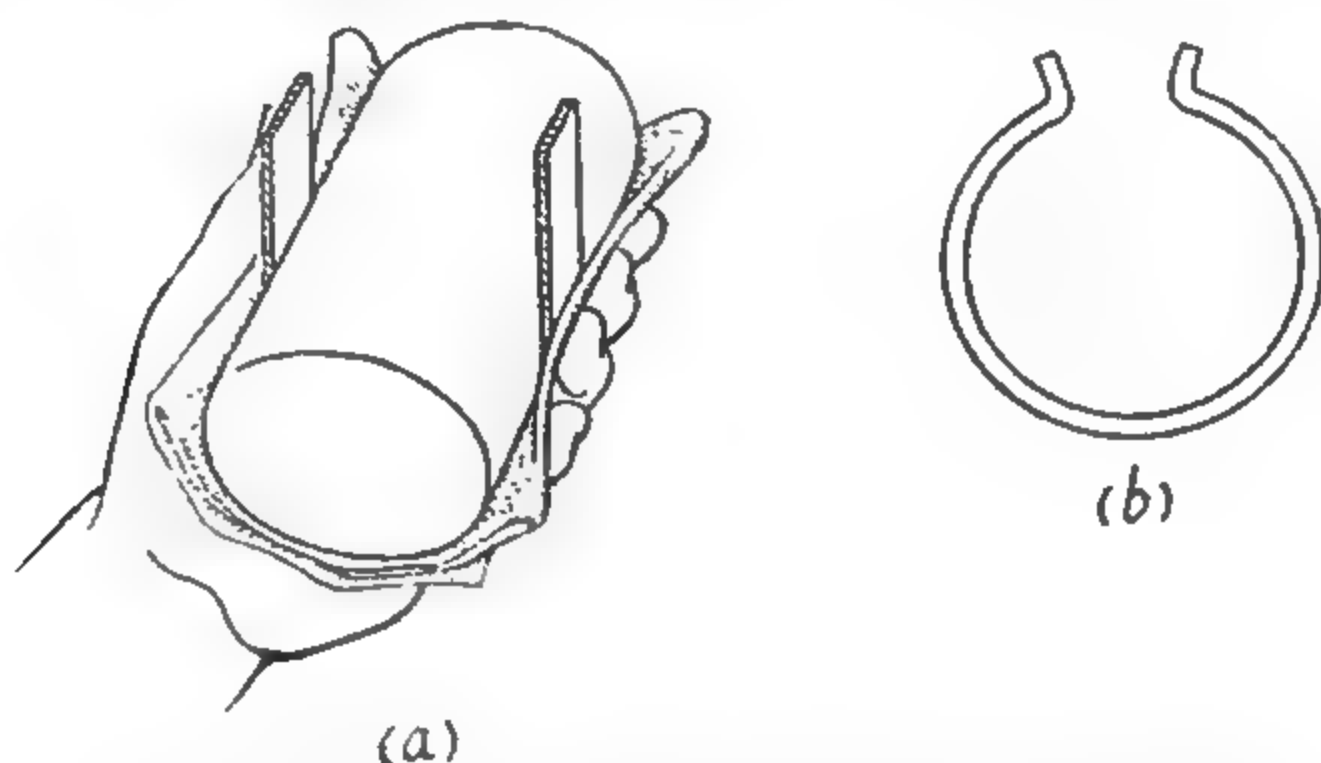


FIG. 68. METHOD OF MAKING TROUSER-CLIPS FROM PERSPEX

for riveting. The holes produced, however, can be used satisfactorily for inserting wire hinges.

(x) *Engraving.* The engraving or scratching of lines on Perspex is one of the chief ways of producing a decorative effect. Various examples can be seen in Plate 8. Any pointed tool, such as a large nail filed to a point, can be used for the purpose. For the best results the scratches should be fairly deep.

When the sheet is to be bent or moulded the engraving should be done before the bending or moulding, as it is often difficult to scratch the lines accurately after these operations. Straight lines are made with the help of a ruler, the material being placed on a dark surface. Curved lines are first traced out with the pointed tool. It is a good idea to draw designs on paper and then gum the latter to the lower side of the sheet. The design can be followed closely on the upper surface with the tool.

**Making Trouser-clips, a Bracelet, or Sugar-tongs.** Making these articles forms a good introduction to the handling of Perspex. The operations involved are cutting, smoothing edges, engraving, softening, and bending.

To make the trouser-clips, cut a strip of  $\frac{1}{8}$  in. or  $\frac{1}{16}$  in. Perspex about 8 in. long and  $\frac{3}{8}$  in. wide. Have ready a couple of clean dusters and a cylindrical tin with a diameter of about  $2\frac{1}{2}$  in.

Soften the strip by placing it on an asbestos mat in the oven (see p. 220). When the strip has been softened remove it (still on the mat) from the oven with a duster. Lift the strip with the duster and lay it over the tin. Place the duster over the strip, lift both the tin and the strip with your left hand and turn them over so that the ends of the strip point upward (Fig. 68 (a)).

With your free hand press the ends of the strip round the surface of the tin, using the second duster for this purpose. Bend the last half inch at each end outward so as to form two right angles. Keep the strip held round the tin for a couple of minutes while it is cooling. Detach the bent strip from the tin and smooth the edges with a file and sandpaper. You will now have one complete trouser-clip, as shown in Fig. 68 (b). Make a second one similarly.

It is important to carry out the working of the material steadily and without fuss when it has been removed from the oven. The plastic will remain soft sufficiently long for you to perform the bending without hurrying, providing that your materials are at hand. If you become agitated, you are likely to make a mess of the job. Remember that if anything goes wrong you can always soften the material once more in the oven and start again.

A Perspex bracelet is an acceptable birthday or Christmas gift for a lady friend. It is made (preferably from  $\frac{1}{8}$  in. sheet) in a similar manner to a trouser-clip, except that the ends of the strip are not bent outward. Also, some decoration must be introduced. This can be done by engraving lines or the lady's name on the strip before bending it. Frosting small sections also improves the appearance. Another suggestion is to cement small pieces of Perspex of various shapes at intervals on the outside of the strip after it has been bent.

A pair of sugar-tongs (illustrated in Plate 8) requires a strip of Perspex about 10 in. long and  $\frac{1}{2}$  in. wide at the middle, tapering down to a width of  $\frac{3}{8}$  in. at the ends. The strip is bent round a piece of wood, the edges of which have been cut to a curve. The ends of the strip are bevelled and given a frosted appearance with fine sandpaper.

**Making a Trinket-box.** This article is both useful and decorative for a dressing-table. To make it the following operations are required: cutting, smoothing edges, softening, bending, cementing, and insertion of hinges. Perspex of  $\frac{1}{16}$  in. thickness should be used.

First cut a piece of sheet in the form of a rectangle 6 in. long and 3 in. wide. Bend the sheet round a cylindrical tin of diameter about

$2\frac{1}{2}$  in. so that the shape shown in Fig. 69 (a) is obtained. Smooth the edges. This piece now forms the body of the box.

Next cut two pieces of sheet 3 in. square to form the sides of the box. Smooth the edges. From each piece cut out small curved

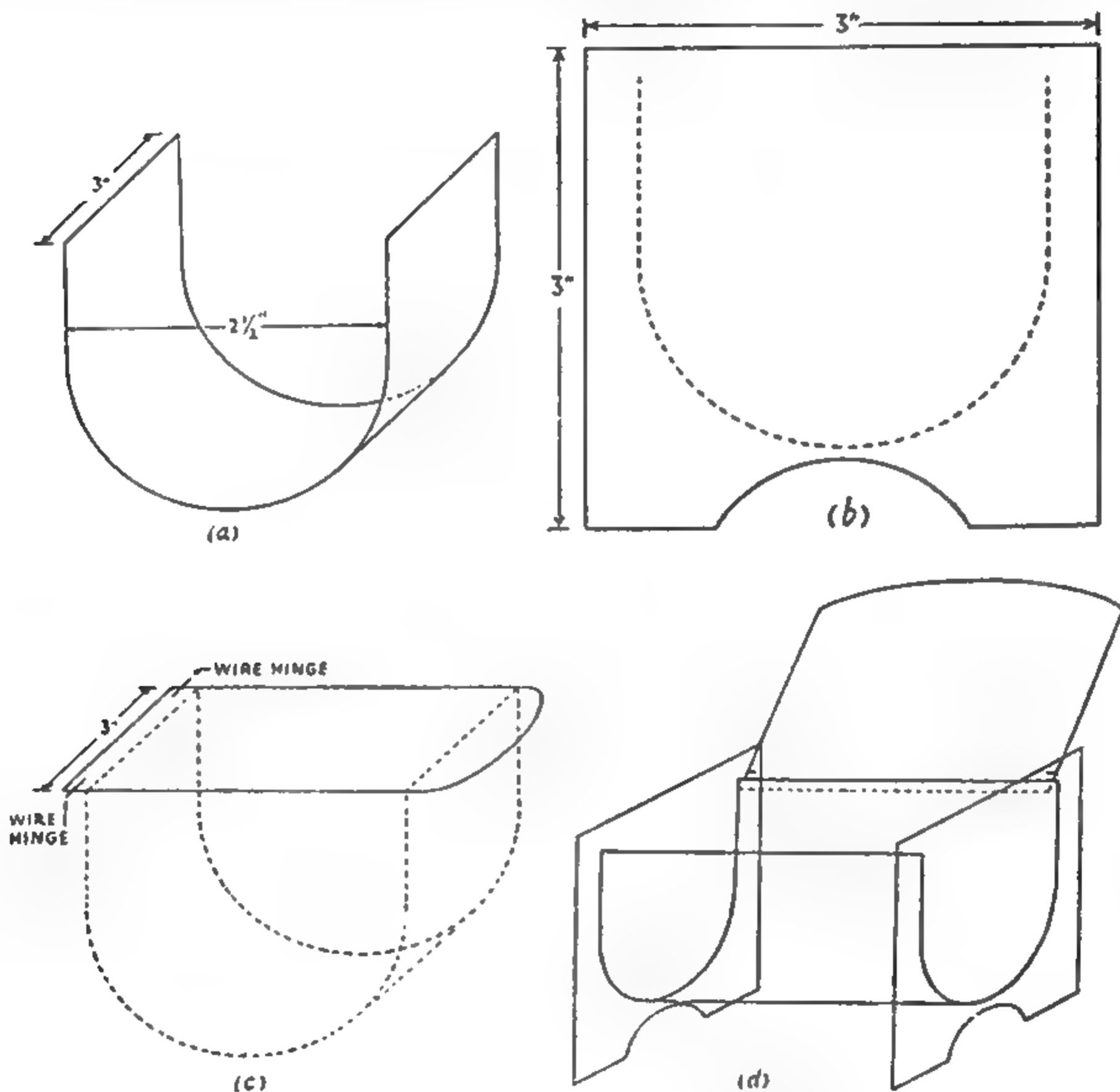


FIG. 69. STAGES IN MAKING A TRINKET-BOX

portions, as shown in Fig. 69 (b), using a fretsaw or heated knife-blade for the purpose.

Another piece of sheet is needed to serve as the lid of the box. The lid has to fit as shown in Fig. 69 (c), across the top of the bent piece already made. It should therefore measure 3 in. wide and be long enough to project about  $\frac{1}{4}$  in. over each side of the bent piece. Smooth the edges of the lid and for decorative effect curve the front of the lid and give it a bevelled edge.

Hinges for the lid are made from a wire paper-clip. Straighten

the wire, hold it in a pair of pliers, and heat the end in a flame. Insert the heated end to a depth of  $\frac{1}{8}$  in. into the side of the lid about  $\frac{1}{8}$  in. from the back edge of the lid. Allow the wire to cool and then snip off the wire so that a length of  $\frac{1}{8}$  in. projects from the side of the lid. Repeat the operation on the opposite side of the lid.

We now come to the assembling of the four pieces. First attach the curved body of the box to one of the sides. Do this by smearing Perspex cement thinly along one of the curved edges and laying this edge carefully on the side-piece. Press the two portions together for

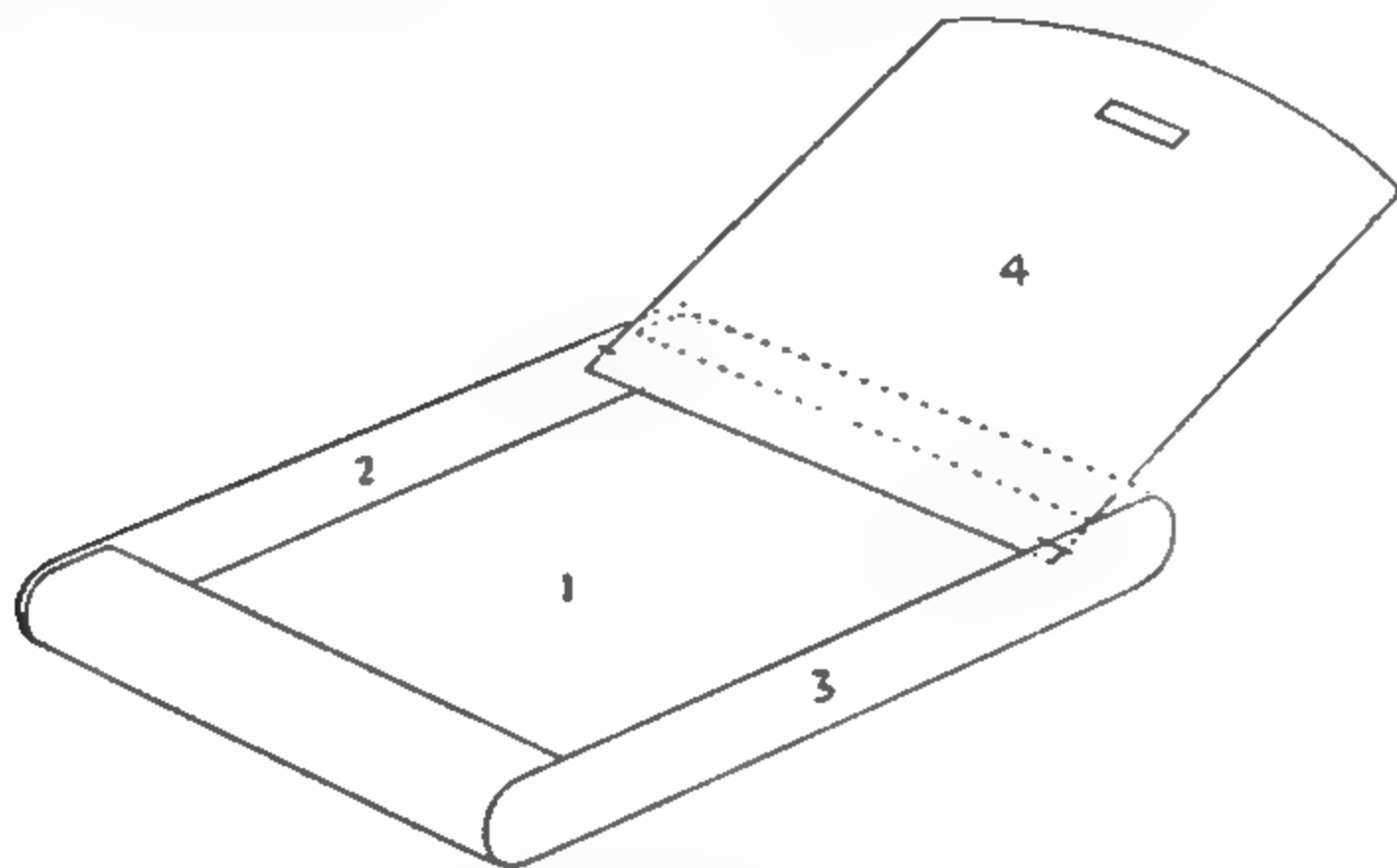


FIG. 70. A HOME-MADE CIGARETTE-CASE

two or three minutes and then leave them undisturbed for an hour or two.

Next make a small hole in the attached side slightly above the level of the curved body and about  $\frac{1}{8}$  in. outside it. Put on the box lid so that one of the hinges passes through the hole.

There remains only the fixing of the remaining side. Lay the latter over the open end of the curved body in the position which it is to occupy. With a sharp point, mark the spot where the second hinge touches the side. At this place make a small hole to receive the hinge. Smear Perspex cement along the curved edge of the body and attach the loose side, allowing the hinge of the lid to enter the hole made for it. Press the box side to the other portion and allow the cement to set. The box will now be complete (Fig. 69 (d)).

The above instructions cover only the essential operations in making the trinket-box. Decorative features, such as the engraving of initials, can be added according to fancy.

**Making a Cigarette-case.** Only a brief description is required in this case, as the operations involved are essentially the same as



those described in making the trinket-box. Perspex of  $\frac{1}{8}$  in. thickness is used. The finished article has a very attractive appearance if it is made with light-green opaque material.

Four pieces of the sheet plastic are needed, as indicated in Fig. 70. These consist of the following:

1. The base. This is made from a piece of sheet 5 in. long and 3 in. wide. The ends are curved upward, as described at p. 223, by bending round a dowel rod or board of suitable size, the edges of the

board being rounded previously.

2 and 3. The sides. These measure about  $3\frac{1}{2}$  in. long and  $\frac{5}{8}$  in. wide. The ends are filed into curves.

4. The lid. This has the same width as the base and a length of about  $3\frac{1}{2}$  in. Wire hinges are inserted in the sides of the lid near one end.

The four pieces are assembled in a similar manner to that described in assembling the trinket-box. If desired, a clip for the lid can be made from a small rectangular

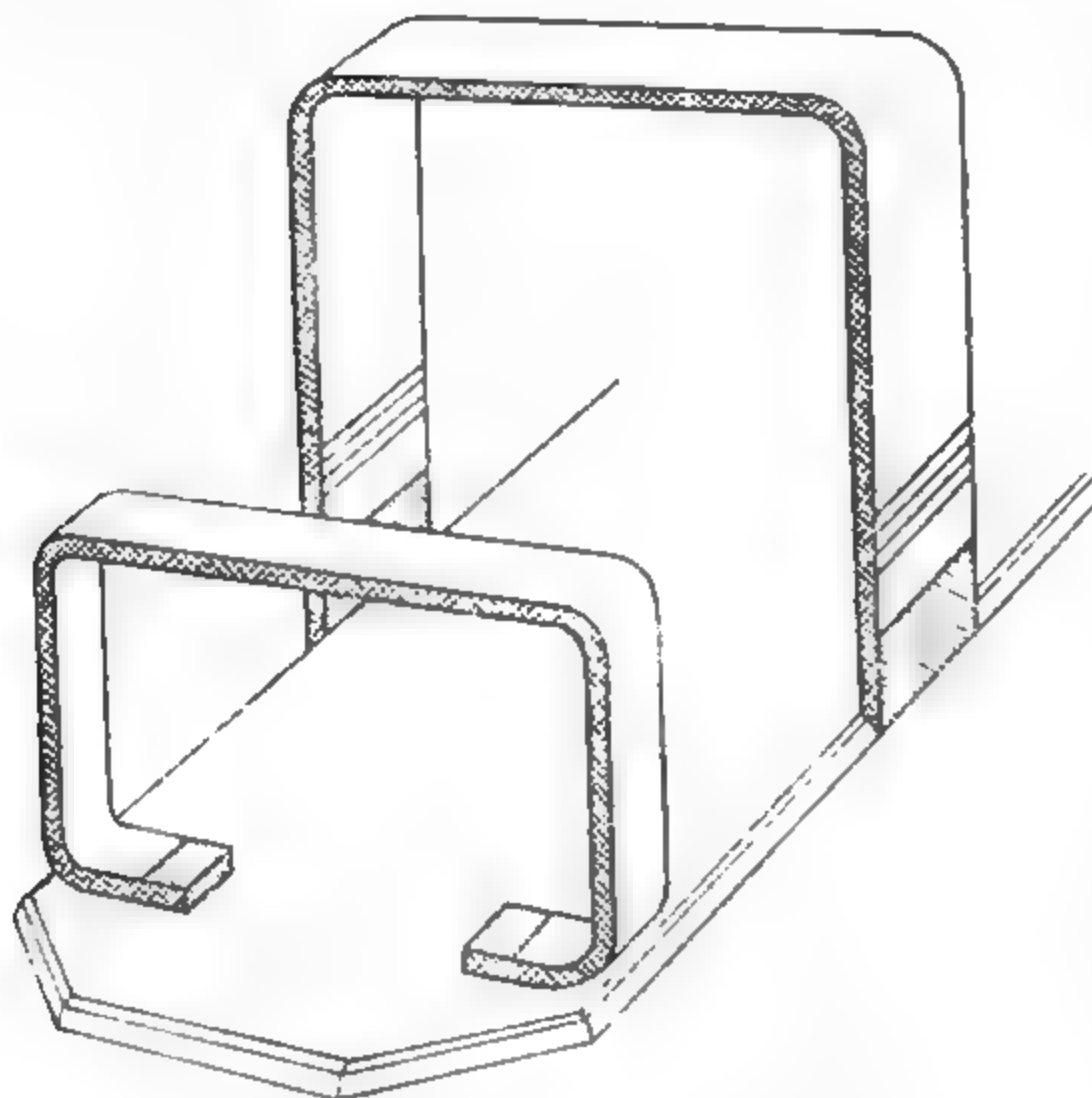


FIG. 71. PARTS OF A TOAST-RACK

piece of Perspex. By bevelling one edge of this piece and also the edge of the upturned end of the base (this should be done before bending), the small piece can be cemented on to the lid in such a position that the two bevelled edges engage when the lid is closed.

**Making a Toast-rack.** A toast-rack constructed from transparent Perspex is both serviceable and ornamental (see Plate 8). The uprights and the handle are made from  $\frac{1}{8}$  in. sheet. For the base  $\frac{1}{4}$  in. sheet is preferable, but the smaller thickness can be used if the larger is not available.

Cut six strips of  $\frac{1}{8}$  in. sheet, each measuring about 8 in. long and  $\frac{3}{8}$  in. wide. These strips form the six uprights (for the sake of clearness only one is shown in Fig. 71). After smoothing the edges shape the strips by bending them round a rectangular tin of suitable size.

Make the handle from a larger and wider strip (12 in. by  $\frac{3}{4}$  in.). For decorative effect rule a few lines across the strip with a sharp

point about two inches from each end. Smooth the edges and bend the strip round a tin of slightly greater width than the tin used for the uprights. By means of fine sandpaper, frost the two ends of the handle on the outside for a length of about an inch.

For the base use a rectangular piece about 9 in. long and  $3\frac{1}{2}$  in. wide. Cut off the corners at an angle of  $45^\circ$  about one inch from each end. After smoothing the sides bevel the upper edges of the base.

The finished article will have a better appearance if the ends of the handle are sunk into the sides of the base. To permit this, file out portions of sufficient width and depth in opposite sides of the base.

To attach the uprights to the base, first insert wire rivets into their lower sides, near the ends, and make small holes in the base at the appropriate places (measure these out). Likewise insert rivets near the ends of the handle on the inner sides and make holes in the sides of the base. Then cement the uprights and handle to the base.

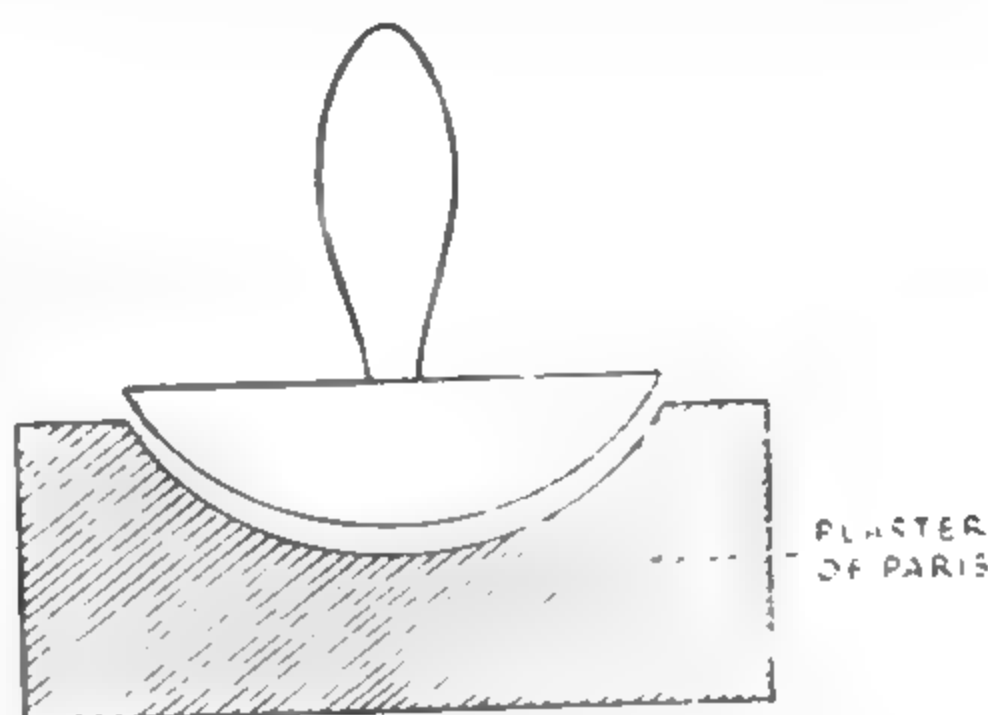


FIG. 72. A SIMPLE PLUNGER AND MOULD

**Making Moulded Articles.** Most of the plastic articles encountered in everyday life are moulded or pressed into shape. It has been mentioned previously (p. 221) that in moulding a double tool is required—namely, a cavity mould of the desired shape and a plunger of the same shape but slightly smaller. The sheet, when it has been softened by heat, is pressed between the two. The following instructions for making simple mouldings can be carried out easily at home with  $\frac{1}{8}$  in. Perspex.

(i) An ordinary wooden stocking-mender makes a suitable plunger (Fig. 72). Use this in conjunction with a cavity mould made from plaster of Paris in a circular tobacco-tin. The tin should have a somewhat larger diameter than the stocking-mender.

Mix the plaster of Paris with cold tea to prolong the period of setting (see p. 66). Fill the tin about three-quarters full with the thick paste and press the stocking-mender into it to the required depth. After removing the stocking-mender smooth the cavity with a finger, and put the tin on one side for twenty-four hours. When the plaster has set rub the inside of the mould well with sandpaper to enlarge it and to smooth the sides.

The plastic sheet to be moulded should be slightly larger than the mould. When the sheet has been softened in the oven lay it over the mould, and press it into the cavity with the stocking-mender. Allow about a minute for cooling and then lift out the plunger. A small saucer-shaped moulding will have been formed.

Cut away the waste material, or flash, from your moulding by means of a fretsaw or heated penknife-blade, allowing a margin for subsequent filing and smoothing of the edge. It is a simple matter to cement three legs to the lower side of the moulding so that a small tripod is formed. Make the legs from thin strips of Perspex and bend them to the required shape. You will now have a dainty

ornament, which can be used as a pin-tray.

(ii) If you possess a fretsaw, a mould and plunger are easily cut out of wood, and a great variety of shapes can be obtained. The portion of wood removed forms the plunger. A screw should be inserted into the latter, so that it can be handled readily. Sufficient clearance between the plunger and mould must be allowed for the introduction of the plastic sheet.

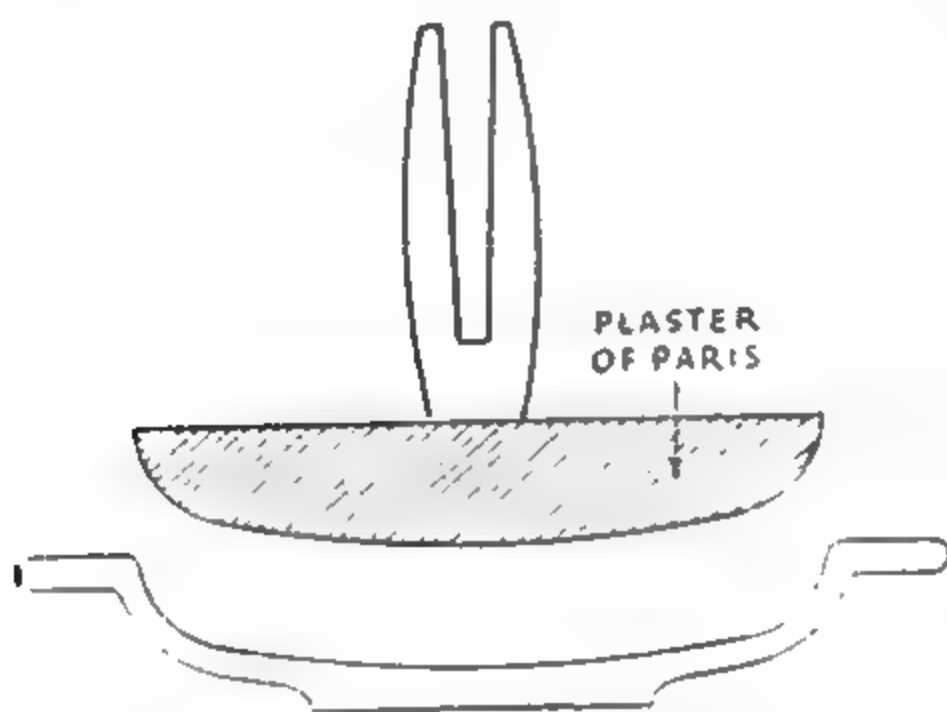


FIG. 73. ALTERNATIVE KIND OF PLUNGER AND MOULD

(iii) You will probably find at home several objects which can be used as cavity moulds. Shallow boxes, bowls, saucers, and trays are suitable for the purpose. In each case, however, it will be necessary to make a plunger. This can be done by filling the object which is being used as a mould with a thick paste of plaster of Paris (first greasing the mould to prevent the plaster from sticking). A clothes-peg inserted into the paste serves as a handle (Fig. 73).

The transparent dish illustrated in Plate 8 was moulded by the method described, a fruit-dish being employed as the mould (Fig. 73). The edge of the moulding was afterwards corrugated by dipping portions of it into boiling water and pressing the softened material on the side of a small tin.

### *Cellulose Acetate*

This material—commonly called ‘non-flam’ celluloid—is not available in suitable sheet form at present, but in normal times it can be bought from firms which specialize in school handicraft

supplies. A brief description of the plastic is included here in the hope that it will be on sale again in the near future.

Cellulose acetate is made by treating cellulose in the form of cotton with a mixture of glacial acetic acid, acetic anhydride, and concentrated sulphuric acid. The resulting cellulose ester can be converted either into fibres for use as artificial silk (*e.g.*, Celanese) or into sheets for use as a plastic.

In many ways cellulose acetate sheet is similar to Perspex. It is easier to handle than the latter but does not possess the same optical qualities. Thus articles made from it have not the brilliant appearance associated with Perspex.

Sheets of cellulose acetate up to a thickness of  $\frac{1}{8}$  in. can be readily cut by scissors or shears. For greater thicknesses a fine-toothed saw can be used. The material is thermoplastic but softens at a lower temperature than Perspex. Immersion in boiling water is sufficient heat treatment for softening. When softened in this way the sheet sometimes acquires a blue bloom on the surface. This can be prevented by adding salt to the water.

The operations of bending, moulding, smoothing edges, and drilling holes are carried out as described previously for Perspex. The surface can be polished with metal polish, but an alternative method is to use a cloth damped with acetone. Cellulose acetate is soluble in acetone. This liquid is also employed for cementing together two pieces of the sheet. Care must be used in handling acetone on account of its high inflammability.

Any of the articles described at pp. 222–228 can be made with cellulose acetate sheet instead of Perspex. It should be remembered, however, that the former softens readily with even moderate heat and loses its shape. This material, therefore, is not suitable for making articles, like toast-racks, which will be exposed to heat.

### *Casein Plastic*

The preparation of casein-formaldehyde plastic at home has been described in Chapter XI (p. 208). This material is sold in sheet form under various trade names, two of the best-known being Lactoid and Erinoid. Unlike Perspex and cellulose acetate, it is not transparent. It can be obtained in various colours, and the usual thicknesses supplied are 3 and 4 millimetres. In the form of rod it is commonly used for knitting-needles. Offcut sheets cost about four shillings a pound.

The plastic sheets are easy to manipulate. They can readily be sawn, bent, moulded, and drilled. Softening occurs with immersion in hot water just below boiling-point for two or three minutes. Polishing can be done by means of metal polish. Pieces are joined

together, after first roughening the surfaces, with a hot or cold water glue. Casco cold water glue is suitable for the purpose.

As in the case of cellulose acetate, the worker should bear in mind that articles made from casein plastic will lose their shape if they are put into hot water.

*Addresses for the Purchase of Plastic Material*

Perspex and other plastic materials and accessories, including adhesives, polishes, etc., can be obtained by post from:

- (i) Plastics (Manchester), Ltd, 11 Whitworth Street, Manchester, 1;
- (ii) E. J. Arnold and Son, Ltd, Butterley Street, Hunslet Lane, Leeds, 10. Price-lists are furnished on request.

## *Approximate Prices of Chemicals*

The prices of chemicals are liable to vary from place to place and from time to time. The list on this page is intended merely to serve as a guide to the reader in making his purchases. Small amounts of chemicals are relatively more expensive than larger amounts.

Alum (chrome) . . . . .	2d. oz.	Ferrous sulphate . . . . .	2d. oz.
Alum (iron) . . . . .	3d. oz.	Ferrous sulphide . . . . .	2d. oz.
Alum (potash) . . . . .	2d. oz.	Formaldehyde (formalin) . . . . .	2d. oz.
Aluminium sulphate . . . . .	3d. oz.	Hydrogen peroxide . . . . .	2d. oz.
Ammonia solution . . . . .	2d. oz.	Iodine (tincture) . . . . .	1s. 6d. oz.
Ammonium carbonate . . . . .	3d. oz.	Iron filings . . . . .	2d. oz.
Ammonium chloride . . . . .	2d. oz.	Magnesium sulphate . . . . .	1d. oz.
Ammonium dichromate . . . . .	3d. oz.	Naphthalene . . . . .	6d. lb.
Ammonium sulphate . . . . .	2d. oz.	Nitric acid (dilute) . . . . .	2d. oz.
Amyl acetate . . . . .	4d. oz.	Red lead . . . . .	2d. oz.
Bleaching powder . . . . .	6d. lb.	Sodium bicarbonate . . . . .	1d. oz.
Boracic acid . . . . .	2d. oz.	Sodium bisulphate . . . . .	2d. oz.
Borax . . . . .	2d. oz.	Sodium carbonate . . . . .	1½d. lb.
Calcium carbonate (chalk) . . . . .	1½d. oz.	Sodium hydroxide . . . . .	2d. oz.
Calcium hydroxide . . . . .	2d. oz.	Sodium silicate . . . . .	8d. lb.
Calcium sulphate . . . . .	5d. lb.	Sodium sulphate . . . . .	2d. oz.
(plaster of Paris)		Sodium thiosulphate . . . . .	3d. oz.
Camphor . . . . .	1s. 6d. oz.	Starch . . . . .	1d. oz.
Carbon (powder) . . . . .	2d. oz.	Stearic acid . . . . .	3d. oz.
Cetyl alcohol . . . . .	8d. oz.	Sulphuric acid (dilute) . . . . .	1d. oz.
Charcoal (lump) . . . . .	1s. lb.	Tannic acid . . . . .	1s. 6d. oz.
Citric acid . . . . .	4d. oz.	Tartaric acid . . . . .	5d. oz.
Cobalt chloride . . . . .	9d. oz.	Triethanolamine . . . . .	8d. oz.
Congo red . . . . .	9d. for 5 gm.	Urea . . . . .	5d. oz.
Copper oxide . . . . .	3d. oz.	Zinc (powder) . . . . .	2d. oz.
Copper sulphate . . . . .	2d. oz.	Zinc sulphate . . . . .	2d. oz.
Ferrous ammonium sul- phate . . . . .	2½d. oz.		

Chemicals and apparatus can be bought by post from: Messrs Oakes, Eddon and Co., Ltd, 99 Prescott Street, Liverpool, 6. Prices will be furnished on application.



## *Chemical Symbols of the Chief Elements*

Aluminium . . . .	Al	Lead . . . .	Pb
Argon . . . .	A	Magnesium . . . .	Mg
Arsenic . . . .	As	Manganese . . . .	Mn
Barium . . . .	Ba	Mercury . . . .	Hg
Bismuth . . . .	Bi	Neon . . . .	Ne
Boron . . . .	B	Nickel . . . .	Ni
Bromine . . . .	Br	Nitrogen . . . .	N
Calcium . . . .	Ca	Oxygen . . . .	O
Carbon . . . .	C	Phosphorus . . . .	P
Chlorine . . . .	Cl	Platinum . . . .	Pt
Chromium . . . .	Cr	Potassium . . . .	K
Cobalt . . . .	Co	Silicon . . . .	Si
Copper . . . .	Cu	Silver . . . .	Ag
Gold . . . .	Au	Sodium . . . .	Na
Helium . . . .	He	Strontium . . . .	Sr
Hydrogen . . . .	H	Sulphur . . . .	S
Iodine . . . .	I	Tin . . . .	Sn
Iron . . . .	Fe	Zinc . . . .	Zn

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